BOLT BERANEK AND NEWMAN INC

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Report No. 2069

March 1971

ANALYSIS OF COMMUNITY NOISE AND A PLAN FOR NOISE CONTROL FOR THE CITY OF BOSTON AIR POLLUTION CONTROL COMMISSION

Charles W. Dietrich
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City of Boston Contract No. 538

Appropriation No. 1-06-41-(29)

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Submitted by:

Bolt Beranek and Newman Inc.
50 Moulton Street
Cambridge, Massachusetts 02138

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TABLE OF CONTENTS

TABLE OF CONTENTS *(Continued)*

TABLE OF CONTENTS *(Continued)*

TABLE OF CONTENTS *(Continued)*

TABLE OF CONTENTS *(Continued)*

LIST OF FIGURES

LIST OF FIGURES *(Continued)*

LIST OF TABLES

LIST OF TABLES *(Continued)*

I. SUMMARY

A. Program Scope

Bolt Beranek and Newman Inc. has undertaken a study of community noise in the City of Boston. This study was monitored by the City of Boston Air Pollution Control Commission, and extended from August 1970 to February 1971. Work was performed under City of Boston Contract 538, Appropriation I-06-41-(29). The scope of the study included the following items:

1. Estimate representative noise levels in the City.
2. Identify and characterize the important noise sources.
3. Set forth criteria for establishing and judging community noise standards.
4. Indicate in general the appropriate methods of noise control.
5. Outline approaches to the control or management of the source-receptor relationship.
6. Compare different approaches for reducing noise.
7. Recommend an initial regulatory program.

The remainder of this section presents a brief statement of the study results.

B. The Present Noise Environment

Information obtained in a recent series of interviews in the Boston, Detroit, and Los Angeles metropolitan areas was analyzed to obtain representative citizen opinions of the amount and sources of neighborhood noise. Response from urban Boston communities indicated that there is a substantially larger percentage of people who feel that their urban neighborhoods are noisy

than do neighborhoods sampled in suburban Boston or in metropolitan Detroit or Los Angeles. Motor vehicles were named most frequently as the source of neighborhood noisiness in all three cities. More than half of the City of Boston interview respondents considered that the drivers of the noisy vehicles could control the noise and reduce it. Aircraft and voices were the sources of noisiness named most frequently after motor vehicles.

The noise levels produced by motor vehicles at a busy Boston surface-street section were grouped by type of vehicle and mode of operation. Vehicles accelerating from a stop tend to produce higher noise levels than vehicles operating at constant speed or in a slow turn. Motorcycles tend to produce higher noise levels than other vehicles, based on the sample analyzed.

Very little information is available on the noise produced by common construction equipment. Therefore, measurements were made at several Boston construction sites. In addition to the noise produced by the construction equipment itself, significant contributions to the noise were made by trucks operating at the construction site. The measurements indicated that construction equipment generally produces noise levels in excess of those produced by surface-street motor vehicles. Most of the construction equipment appeared to have little or no provision for noise control, and in many cases mufflers on the intakes and exhausts of the equipment engines would provide sizable reductions in the noise levels produced by the equipment.

C. Noise Criteria

A common effect of noise is to interfere with ongoing speech communication. The presence of noise levels such as were measured

from motor vehicles or construction equipment can reduce the distance over which speech can be heard from the order of 10 ft to the order of 1 ft. Noise can also interfere with sleeping, can make falling asleep more difficult, and can produce undesirable physiological effects. Continued exposure to high noise levels can also produce hearing damage, although the noise levels involved in producing such damage are not generally encountered in community (or outdoor) situations and were not the subject of this study.

D. Community Noise Standards

Several groups have recommended noise standards (goals) for adoption in community situations. These standards are useful both as measures of the effectiveness of a noise control program and as guides in land use management. The interim standard proposed for the City of Boston in this report is derived from a standard under consideration by the U.S. Department of Housing and Urban Development. The noise measured in Boston and several other cities is generally in excess of the proposed interim standard, even though the proposed standard is less stringent than some standards recommended elsewhere. The proposed interim standard therefore represents a first step goal. As the impact of regulatory measures is felt and the noise levels are reduced, we recommend that the City consider making the standard more stringent so that it eventually describes what is believed to be a highly desirable situation.

E. Current Legal Status of Commission

An appraisal of the current status of the enabling and enforcement powers granted by the General Laws of the Commonwealth and the Ordinances of the City indicates that the Boston Air

Pollution Control Commission is now in a position to propose an initial regulatory program for noise control in the City. Further strengthening of the General Laws may be necessary to categorize noise as a pollutant and thus to clarify the enforcement powers and permissible penalty structure available to the City. Similarly, further extension of City ordinances may be needed to pass on such powers to the Boston Air Pollution Control Commission and to clarify the role of coordinate enforcement bodies such as the Police Department.

F. The Case for a Stepwise Regulation Program

Consideration of the current status of the Commission and the anticipated acceptability of noise control within the City leads to the recommendation that an initial set of regulations be proposed which are practical and readily capable of being put into force. This deliberately puts off to the future the introduction of a more extensive regulatory program containing noise controls which are more difficult to enforce.

G. Scope of Proposed Initial Regulations

Accordingly, four general categories of noise emissions have been selected as targets for the initial regulatory program, namely:

1. land use noise emissions, to be restricted according to zoning districts,
2. construction site noise emissions,
3. new vehicles for sale or lease whose noise emission performance must meet restrictive standards when delivered from the manufacturer,

4. new powered outdoor equipment for sale or lease, to be restricted as above.

H. Basis for Regulations

Values for maximum permissible noise levels have been proposed based both on experience in other cities and on targets set for new equipment which are generally agreed to be achievable by the manufacturing community.

I. Applicability to Airport Ground Operations and Aircraft Overflight Noise

The scope of this study and hence the recommended regulations did not include explicit consideration of methods of abating aircraft operation noise. The results of the neighborhood interview survey indicate that aircraft are viewed as important noise sources by a large number of Boston residents. However, methods of abating noise at Logan International Airport were the subject of a previous study*, and this subject is undergoing further study by the Massachusetts Port Authority, the Federal Aviation Administration,. and other interested groups. If the City adopts the proposed noise regulations as a function of zoning districts, the City will have the mechanism for controlling the noise from aircraft *ground* operations under the regulations for land use noise restrictions according to zoning districts as recommended in this report. It is our current understanding that noise from aircraft *flight* operations can be regulated only by the airport operator (as the landlord who may influence scheduling) or by the Federal government (through air traffic control or aircraft certification).

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*"Aircraft Noise and Airport Neighbors," Department of Transportation and Department of Housing and Urban Development, Report IANAP-70-1, March 1970.

J. Proposed Measurement Procedures

In concert with the proposed regulations, a set of measurement procedures is proposed to assure that technically sound, legally defensible measurements are made in carrying out the regulatory program. Similarly, manpower and equipment requirements have been estimated, and the qualifications of enforcement personnel established.

K. Practicality of Quieting

Methods for achieving quieted equipment or operations have been reviewed and they indicate the extent of noise control progress which is possible under an active regulatory program. The maximum levels cited in the regulations are judged technically achievable, although admittedly costly. Analysis of cost-effectiveness of quieting measures and cost-benefits resulting to the community are considered outside the scope of this current study.

L. Next Steps

Recommended next steps include:

1. Review and refining of current findings with concerned regulatory bodies.
2. Development of strengthened back-up Ordinances and General Laws.
3. Agreements with coordinate enforcement bodies.
4. Ensure compatability of the Zoning Code and the proposed new noise regulations.

5. Finalization and issuance by the Commission of initial noise regulations and attendant measurement procedures.

M. Future Programs

For the future, there will undoubtedly be a need for an expanding noise control program including such elements as the following (not necessarily in order of priority):

1. Horn blowing restrictions.
2. Additional regulations restricting running motors while vehicles are stationary.
3. Public awareness and education program.
4. Additional regulations restricting noise emissions from vehicles in use (possibly a matter for the Commonwealth to consider).
5. Additional regulations concerning indoor noise control through tightened building codes.
6. Participating in the airport noise abatement program.
7. Extending regulatory program into the field of occupational health and safety.

II THE BOSTON NOISE ENVIRONMENT

A. Representative Citizen Opinions

The following analysis is based upon a survey of reactions to motor vehicle noise conducted in the spring of 1970 by Bolt Beranek and Newman Inc. for the Automobile Manufacturers Association. A formal report of the survey is in preparation. Meanwhile, the AMA has given permission to use available survey data in this report. The analysis of data related specifically to motor vehicle situations was done under AMA sponsorship; the analysis of data related to neighborhood noisiness in general and to several sources of noise was sponsored by the City of Boston under the present program.

Telephone interviews were conducted with approximately 20 adults in different households at each of 25 sites in the Boston and in the Los Angeles metropolitan areas and at 10 sites in the Detroit metropolitan area, a total of approximately 1200 respondents at 60 sites. The sites were randomly selected from the areas; within each site the households where interviews were conducted were selected to maximize the uniformity of exposure to neighborhood noise.

When the sample was drawn, nine of the sites fell in the City of Boston: two in East Boston and one each in Charlestown, Back Bay, Allston, Roxbury, Dorchester, Mattapan, and Roslindale. Of the 16 sites that fell in the suburban Boston area, two sites each were in Arlington, Medford, Waltham, and Brookline and one each in Wakefield, Melrose, Everett, Cambridge, Newton, Quincy, Weymouth, and Randolph.

While the interviews were directed primarily at the 549 respondents who were annoyed by motor vehicle noise, (46% of total) all

respondents were asked to rate the noisiness of their neighborhoods on a seven-point scale that varied from "not noisy at all" (scored 1) to "unbearably noisy" (scored 7). If they believed their neighborhoods to be at all noisy, they were asked to indicate the sources of the noise and to say what percentage of the "noisiness" was contributed by each source. The sources suggested for neighborhood noise were aircraft, construction, industries, motor vehicles, "personal machines" (power mowers, snow blowers, etc.), radio and TV sets, and voices.

Since the data were gathered for a purpose quite different from that which guides this report, they should be considered suggestive rather than conclusive. We are particularly concerned that, although 180 households are represented in the City of Boston, they are clustered in only nine randomly chosen locations. A more finely divided sample of the City would be desirable. While it is impossible to designate the degree to which the sample locations are representative of the City, our best estimate is that the sample is sufficiently representative to compare Boston with other areas, particularly when differences are found to be large, as in Tables 1 and 3; however, the sample is probably not sufficiently representative that absolute percentages or average scale scores can be projected on the City as a whole. To reinforce this estimate, we shall, in what follows, refer to the samples from which data were taken rather than to the total populations of Boston or of the areas to which Boston will be compared.

1. Noisiness

The data yield information on the noisiness of the nine neighborhoods that were sampled in Boston as experienced

by the people who live in them. To derive this information, we must ask two questions: "How extensive is the noise?" and "How intense is the noise?" Evidence bearing on the first question is the number or percentage of people who regard the environment as noisy; evidence bearing on the second is the average intensity felt by those who regard the environment as noisy as measured by the "noisiness" scale mentioned above.

TABLE 1. Extent of Neighborhood Noisiness, by Areas

Opinion	Boston		Metropolitan Area		
	City	Suburbs	Boston	Los Angeles	Detroit
Percentage of those responding who say their neighborhoods are:					
Noisy	86	71	77	68	67
Not Noisy	14	29	23	32	33
Number:					
Responding (base for %)	180	317	497	495	199
Not responding	0	2	2	7	1
Interviewed (Total)	180	319	499	502	200

Table 1 shows that 86 percent of those interviewed in the City of Boston rated their neighborhoods between two and seven on the noise scale; that is, they thought their neighborhoods were noisy. This contrasts with 71 percent of the people interviewed in the Boston suburbs and with 68 percent and 67 percent respectively of those questioned in the metropolitan Los Angeles and Detroit areas.

TABLE 2. Intensity of Neighborhood Noisiness, by Areas

Opinion	Boston		Metropolitan Area		
	City	Suburbs	Boston	Los Angeles	Detroit
Average noisiness score	3.6	3.1	3.4	3.1	3.2
Number:					
Who believe their neighborhoods to be:					
Noisy (base for avg)	154	226	380	337	134
Not noisy	26	91	117	158	65
Not responding	0	2	2	7	1
Interviewed (Total)	180	319	499	502	200

Table 2 indicates that while those who judge the neighborhoods that were surveyed in the Boston suburbs and in the metropolitan areas of Detroit and Los Angeles as noisy averaged 3.1 or 3.2 points on the noisiness intensity scale described above, those who judged the neighborhoods that were surveyed in the City of Boston to be noisy averaged 3.6 points on the scale. On the scale, a score of "three" was labelled "quite noisy"; a score of "four" was labelled "definitely noisy."

In short, neighborhoods in the Boston City sample have a substantially larger percentage of people who feel that their neighborhoods are noisy than do neighborhoods that were sampled in the Boston suburbs or in the metropolitan areas of Los Angeles or Detroit. There is evidence too, that among those interviewed who do regard their neighborhoods as noisy, the neighborhoods

surveyed in the City of Boston appear somewhat noisier on the average than the neighborhoods that were surveyed elsewhere.

2. Sources of Noise

We turn now to the question, "What is the source of Boston's noise?" The data that bears on this question is in Table 3. Like Tables 1 and 2, Table 3 separates the City of Boston from the suburbs and gives data for the three metropolitan areas, Boston, Los Angeles and Detroit. Each respondent who rates his neighborhood as at all noisy (from two to seven on the "noisiness" scale) was asked to indicate the percentage of the noise that came from each of the various sources. (When a respondent assigned less than 100 percentage points to all sources, the remainder was coded as "not ascertained").

Table 3 evaluates the contribution of each of the sources by the "weighted percent" statistic. This is calculated by adding the percentages for each source separately and dividing each source's total by the total number of persons in that area who felt their neighborhoods were noisy regardless of whether they named the source or not. This calculation takes into account both the number of persons who designated the source and the weight (percentage) each of them gave it. Table 3 says nothing about the magnitude of the noisiness; magnitude data are given in Tables 1 and 2. Rather, it represents the contribution of each source named to the total noise in the neighborhoods that were sampled.

When "weighted percents" were calculated for sources of noise in the Boston City neighborhoods in the sample, the contribution of aircraft (as shown in the "Boston City (unadjusted)" column)

TABLE 3. Sources of Neighborhood Noisiness, by Areas

Source	Weighted Percent[1]					
	Boston			Metropolitan Area		
	City		Suburbs			
	(Unadjusted)	(Adjusted)[2]		Boston	Los Angeles	Detroit
Aircraft	25	19	11	17	16	5
Construction	5	5	<1	2	1	-
Industrial noise	1	1	<1	<1	-	1
Motor vehicles	34	36	66	53	51	68
Other engine-powered equipment	<1	<1	<1	<1	2	4
Radio and TV sets	2	3	1	2	3	1
Voices	20	22	10	14	8	13
Other noises	7	8	4	5	8	2
Not ascertained	6	6	7	6	10	5
Total	100	100	99	99	99	99

[1]The "weighted percent" designates the contribution of each source to the total noise environment. See text for derivation.

[2]The "adjusted Boston City" calculations correct for oversampling in East Boston. See text for explanation and derivation.

was 25 percent. This may be a serious overestimate since two of the nine neighborhoods studied were in East Boston. To compensate for this overestimate, we have also calculated these weighted percentages by assuming that only one site in East Boston was sampled; this was done by reducing the contribution of the two East Boston neighborhoods from two-ninths to one-eighth. The results are shown in the "Boston, City (adjusted)" column.

It appears from Table 3 that motor vehicles are the chief source of neighborhood noise in all areas, followed by aircraft and voices. Together these three sources account for between 75 and 80 percent of the noisiness in the neighborhoods that were studied. It is also notable that those neighborhoods that were in the Boston and Los Angeles metropolitan areas are comparable so far as the distribution of noise sources are concerned.

However, the contributions of various sources of noise are quite different for the neighborhoods studied in the City of Boston from those studied elsewhere. While still the paramount source, motor vehicles contribute about 35 percent rather than from 50 percent to nearly 70 percent of the noise as they do in other areas. Even when the oversampling in East Boston is adjusted for, aircraft noise is at least as important in the City of Boston as elesewhere. Voices are nearly twice as important in the Boston City sample as in the others, while construction noise, which makes a small, but appreciable contribution in Boston (5 percent) is scarcely to be found anyplace else.

Some of the reasons for these differences are to be found in the physical distribution of sources in the area. Logan Airport is closer to the city than to most of the suburbs; like Logan, Los Angeles International

Airport is "close in" and borders the area that was surveyed while Detroit Metropolitan Airport is farther out and is outside the area that was surveyed. The greater contribution of voices and construction to noise within the City of Boston may be traceable to the greater density of the areas that were surveyed. A review of the neighborhoods in which interviewing took place shows a greater concentration of multi-dwelling units and less space between dwellings in the City of Boston than in other locations including those within the city limits of Detroit and Los Angeles. Our general knowledge of these cities indicates that Boston's greater compactness reflects the true situation and is not an artifact of sampling.

3. Motor Vehicle Noise

Although motor vehicle noise is *comparatively* less important a source of noise in the neighborhoods that were sampled in the City of Boston than in similar neighborhoods elsewhere, in *absolute* terms motor vehicle noise is probably as serious a problem in these Boston neighborhoods as it is in others that were studied.

The data supporting this conclusion are presented in Table 4. In the course of the survey, respondents were asked if they were ever annoyed by motor vehicle noise; if they replied affirmatively, they were asked to describe the motor vehicle situations that annoyed them and to rate these situations on a seven-point scale of annoyance. Table 4 describes data for respondents who were annoyed by motor vehicle noise while they were at home. The extent of this annoyance is described by the rate of situations per respondent; the intensity of the annoyance is described by the average level of the annoyance scale. It is apparent that on both counts, the Boston metropolitan area is more annoyed by motor vehicle noise heard at home than either the Los Angeles or the Detroit areas. It is also apparent that annoyance with motor vehicle noise in the City of Boston is about as widespread and intense as it is in the Los Angeles and Detroit metropolitan areas.

The discrepancy between the fact that the problem of motor vehicle noise is as large in the neighborhoods sampled in Boston as in those sampled in other areas (Table 4) even though motor vehicles are proportionately a less important source of noise in these Boston neighborhoods (Table 3) is explained in Tables 1 and 2. They show noise in the sampled Boston City neighborhoods to be more extensive and probably more intense than that in other areas. The noise problem is larger in the Boston City neighborhoods that were sampled, hence, although the motor-vehicle-noise problem is about the same size here as in the neighborhoods in the Detroit and Los Angeles samples, it is not as large proportionately.

Reviewing the results of Tables 1 through 4, we find that the total noise problem is larger in the sampled City of Boston neighborhoods than in the other neighborhoods sampled. Thus, although the motor-vehicle-noise problem is about the same *absolute* size in all areas sampled, it is seen *proportionately* as a smaller part of the total problem in the City of Boston than in the other areas sampled.

4. Noise and Public Opinion

In the survey, those situations that resulted in annoyance with motor vehicle noise were examined in greater detail than were those from other sources. In the City of Boston, 107 such situations were studied. The 76 shown in Table 4 occurred in people's neighborhoods; the other 31 occurred either at work or while respondents were driving or walking. The study of these situations throws light on two questions relative to how people look at motor vehicle noise: (1) Is motor vehicle noise annoyance looked on as idiosyncratic or as a matter of public opinion? (2) Are annoyance levels influenced by people's perceptions of drivers as noisemakers?

TABLE 4. Annoyance with Neighborhood Traffic Noise: Number and Rate of Annoying Traffic Situations Named and Average Level of Annoyance by Location

	Boston		Metropolitan Areas		
	City	Suburbs	Boston	Los Angeles	Detroit
Number of respondents	180	319	499	502	200
Number of annoying situations	76	172	258	195	90
Situations per respondent	0.42	0.54	0.50	0.39	0.45
Average level of annoyance	4.1	4.4	4.3	3.8	4.0

TABLE 5. Degree to which Annoyance is Perceived as being Shared: Boston City Sample

Respondent believes that the Situation that Annoys him is Annoying to:	%
Himself alone	5
Friends and acquaintances he knows	11
The public in general	74
(Not ascertained)	10
Total	100
Number of Annoying motor vehicle situations in Boston City sample (Base) =	107

From Table 5, three-fourths of the situations in the City of Boston that were described to interviewers were believed by those who experienced them as being public rather than idiosyncratic annoyances. These people did not believe they were alone in their annoyance.

Secondarily, respondents seem to be less annoyed if they feel that the noise is the fault of the machine itself rather than the fault of the operator of that machine.

TABLE 6. Degree of Control that the Driver has over the Noise: Boston City Sample

Driver's Control of Noise is Perceived as:	%	Average Level of Annoyance
Easy	43	4.7
Hard	14	4.2
Impossible	38	3.8
(Not ascertained)	5	2.8
Total	100	4.2

Number of annoying motor vehicle noise situations in Boston City sample (base) = 107

We have two measures of perceived driver fault; whether he could control the noise, and whether he is driving legally. Table 6 shows that the amount of annoyance that respondents expressed with motor-vehicle-noise situations is in part a function of the degree of control they believe a driver has over the noise his vehicle is making. In fact, one can account for eight percent of the variance in annoyance based on this perception alone. Furthermore, in over half the situations uncovered in interviews with Boston City residents, respondents thought drivers could control the annoying noise if they tried.

TABLE 7. Perception of Legality of Motor Vehicle Operation

Operation is perceived as being:	%	Average Level of Annoyance
Legal	59	3.8
Illegal	22	5.1
(Not ascertained)	19	4.4
Total	100	4.2

Number of annoying motor vehicle noise situations in Boston City sample (base) = 107

One can account for eleven percent of the variance in annoyance from motor vehicle noise situations by knowing whether respondents feel drivers are operating their vehicles legally. Table 7 shows annoyance levels vary by 1.3 scale points based on this perception. Both this and the finding concerning perceptions of driver control over noise are statistically significant.

Taken together, these data indicate some basis for a public opinion that would support action to abate the most important source of neighborhood noise. Most of the noise from motor vehicles that now annoys Bostonians is not considered to come from illegal operations, but it is held to be a public nuisance; the annoyance is not thought to be idiosyncratic. Moreover, more than half of the situations are thought to be within the control of motor vehicle operators.

5. Summary of Citizen Opinions

More people interviewed in the City of Boston feel that their neighborhood is noisy than do people interviewed in other areas. This noisiness is also perceived at a somewhat greater level of intensity in Boston. In all the locations that were studied, motor vehicles are the chief contributor to neighborhood noisiness; however, this predominance is less pronounced to those interviewed in the City of Boston than elsewhere. In the City of Boston, voices, aircraft, and construction noise contribute proportionately more to noise in the neighborhoods that were sampled than in other locations studied. However, from an absolute standpoint, motor vehicles make as large a contribution to noisiness — or at least to noise annoyance — in the City of Boston neighborhoods as they do elsewhere. By and large, vehicle noise is looked upon by respondents in Boston as a public nuisance. While less than one-fourth of the vehicle noise intrusions seem to come from illegally operated vehicles, over half of these intrusions appear to be subject to driver control. As expected, annoyance is significantly higher in cases where drivers might control the noise over those cases where drivers are considered to be operating illegally.

B. Representative Motor Vehicle Noise Levels

The noise produced by surface automotive vehicles is almost always a predominant component of urban noise. As a sample of the motor vehicle noise levels encountered in the City of Boston, a two-hour recording of traffic noise was analyzed. The recording was made on 16 April 1970 at the intersection of Boylston Street, Massachusetts Avenue, and the Massachusetts Turnpike. Figure 1 is a sketch of the measurement site. This site was chosen to provide a combination of stop-and-go traffic on surface streets and free-flowing highway traffic.

The recording was made on a dual-channel tape recorder. One channel was used to record the traffic noise. The other channel was used for voice annotations, describing the vehicle type (tractor truck, oil delivery, panel truck, refuse truck, bus, motorcycle, etc.), vehicle location (street and direction), and mode of operation (constant speed, accelerating, slow turn, etc.). No attempt was made to describe the sources of all traffic noises, but only the noise events that were clearly distinguishable from the background noise of other traffic were noted. In the analysis all noise levels were normalized to a distance of 50 ft. An adjustment to the noise levels of westbound Turnpike events was included to take into account the effect of sound energy reflected from the building on the opposite side of the Turnpike. Noise levels from eastbound Turnpike events were not included because the microphone was partially shielded from the eastbound noise sources.

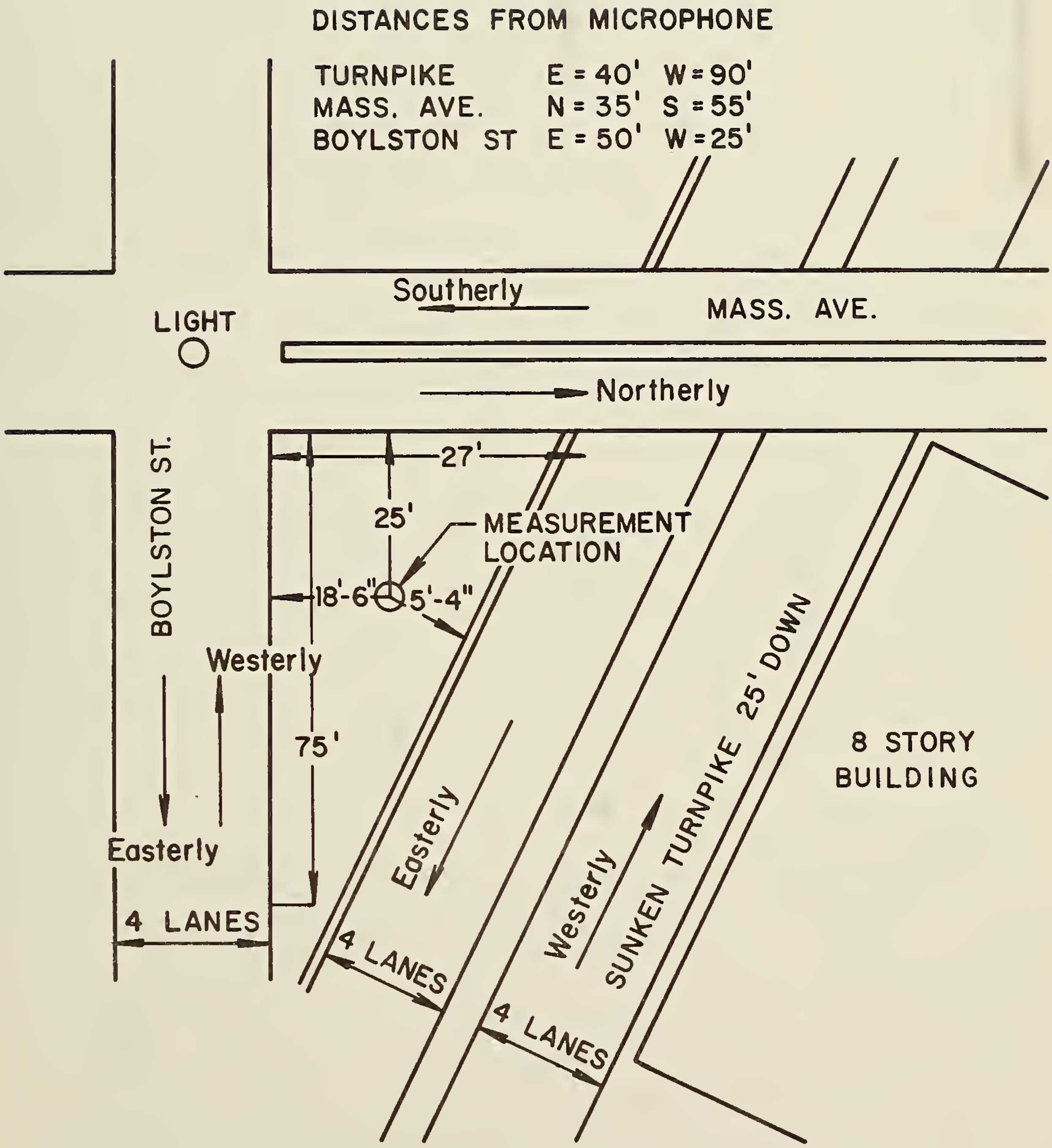

FIG.1 SKETCH OF MOTOR VEHICLE MEASUREMENT SITE
(Not To Scale)

Figure 2 shows the distribution of noise levels obtained from the noisier vehicles in freely-flowing traffic on the Turnpike. (In this figure and in much of the remainder of this report, noise levels are given in terms of the single-number scale of A-weighted sound level. This scale has been found to correlate extremely well with subjective response to noise. Further discussion of the choice of scale is given in Appendix A.) The distributions of noise levels produced by the noisier tractor trailers, other trucks, and buses appear slightly less noisy than the other sources shown in the figure. Figure 3 is a comparison of the 37 measurements of tractor trailer noise made at this position with a more extensive set of measurements made previously on freely-flowing tractor trailer vehicles (every truck) on Route 128. Detailed differences between the two distributions may be associated in part with the Turnpike measurement procedure, which excluded the data from the quieter vehicles. Thus, noise levels less than approximately 81 dB(A) (normalized to 50 ft) for vehicles traveling westbound on the Turnpike are not included.

Figures 4a and 4b show the distribution of noise levels from vehicles traveling on the surface streets (Boylston Street and Massachusetts Avenue). The four highest auto noise levels were produced by sports cars. Although there are very few data samples, the noise levels associated with motorcycles are somewhat higher than those associated with trucks, buses and autos. It should be pointed out again that the noise levels measured for autos are only those of the noisier, clearly identifiable vehicles, and the vast majority of auto noise levels were well below those shown in Figs. 4a and 4b.

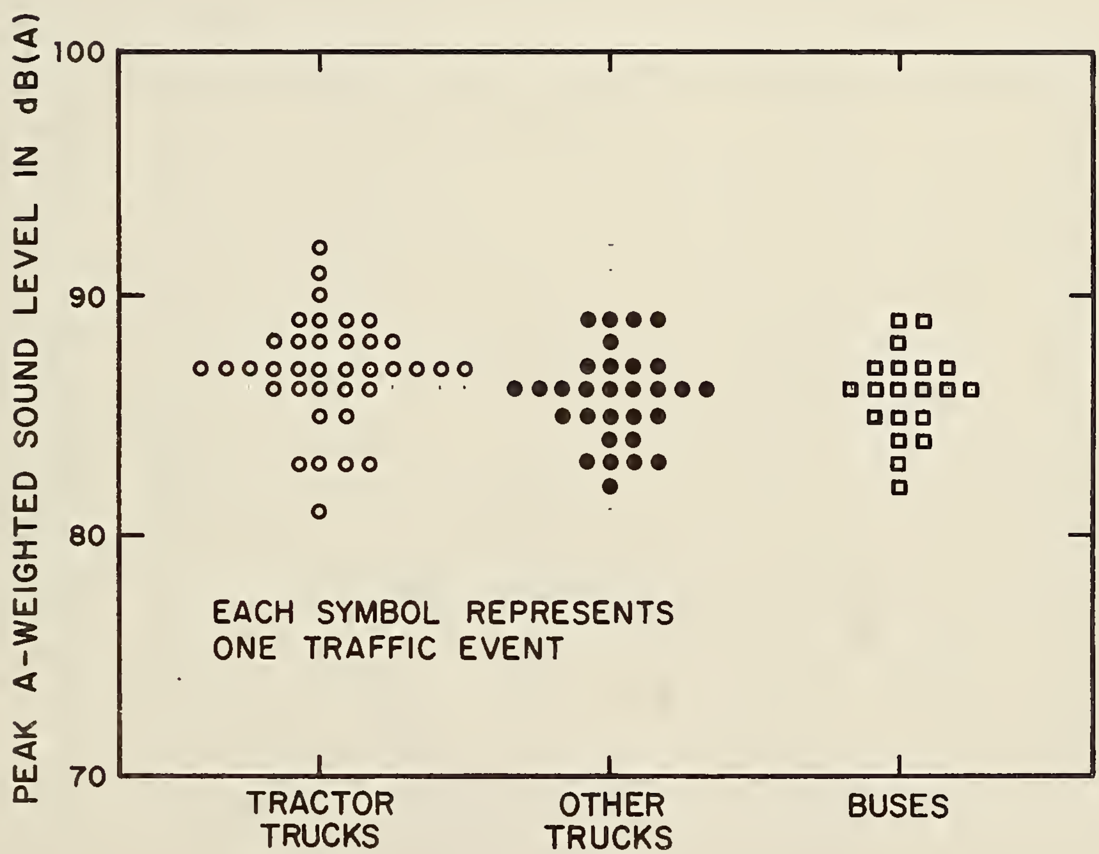

FIG.2 NOISE OF FREELY-FLOWING BOSTON TURNPIKE TRAFFIC
(Data Normalized To 50 ft)

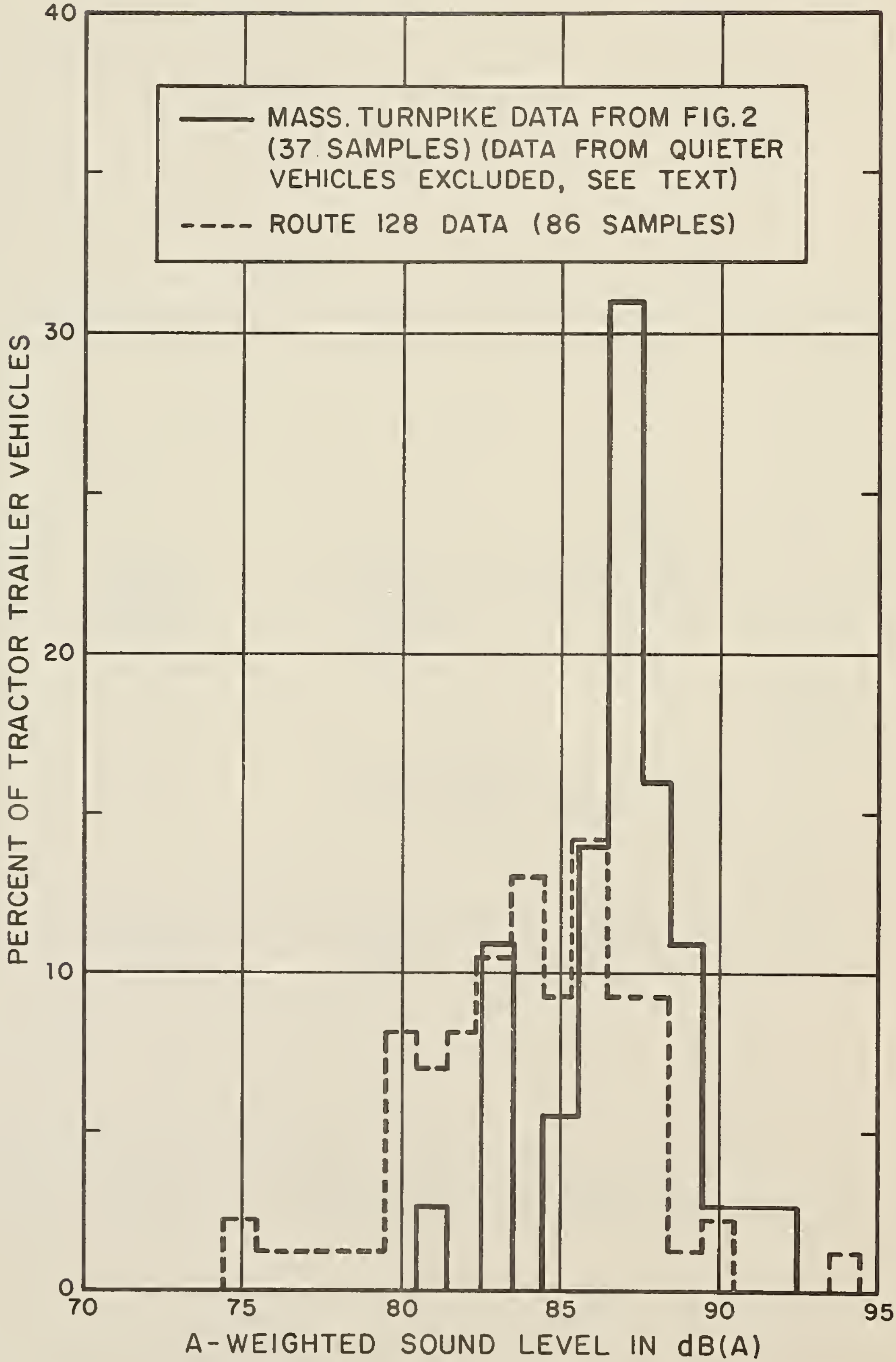

FIG. 3 DISTRIBUTIONS OF NOISE LEVELS FROM CRUISING TRACTOR TRAILER TRUCKS (Data Normalized to 50 ft)

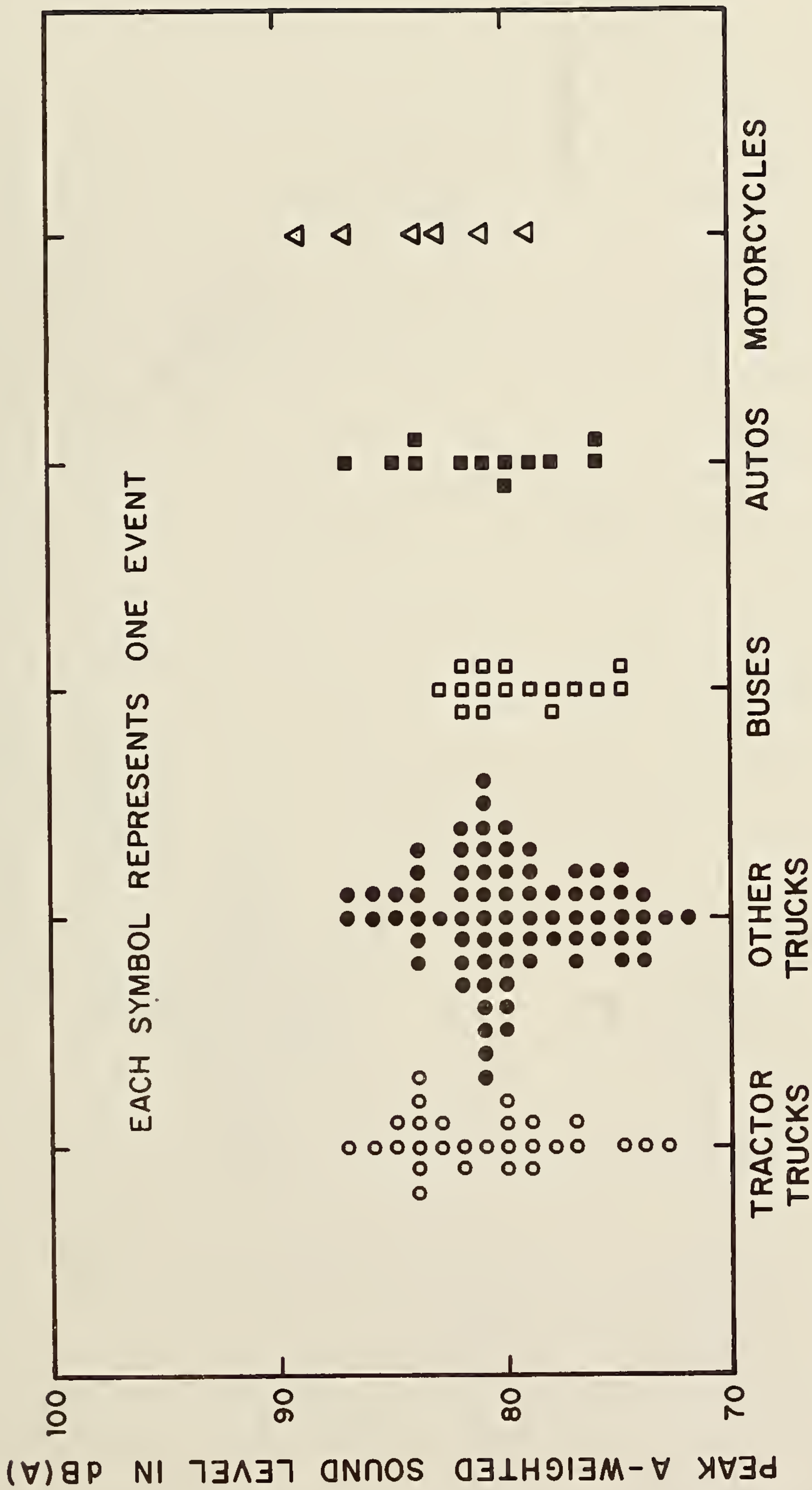

FIG.4a NOISE OF BOSTON SURFACE-STREET TRAFFIC GROUPED BY VEHICLE TYPE. (Data Normalized To 50 ft)

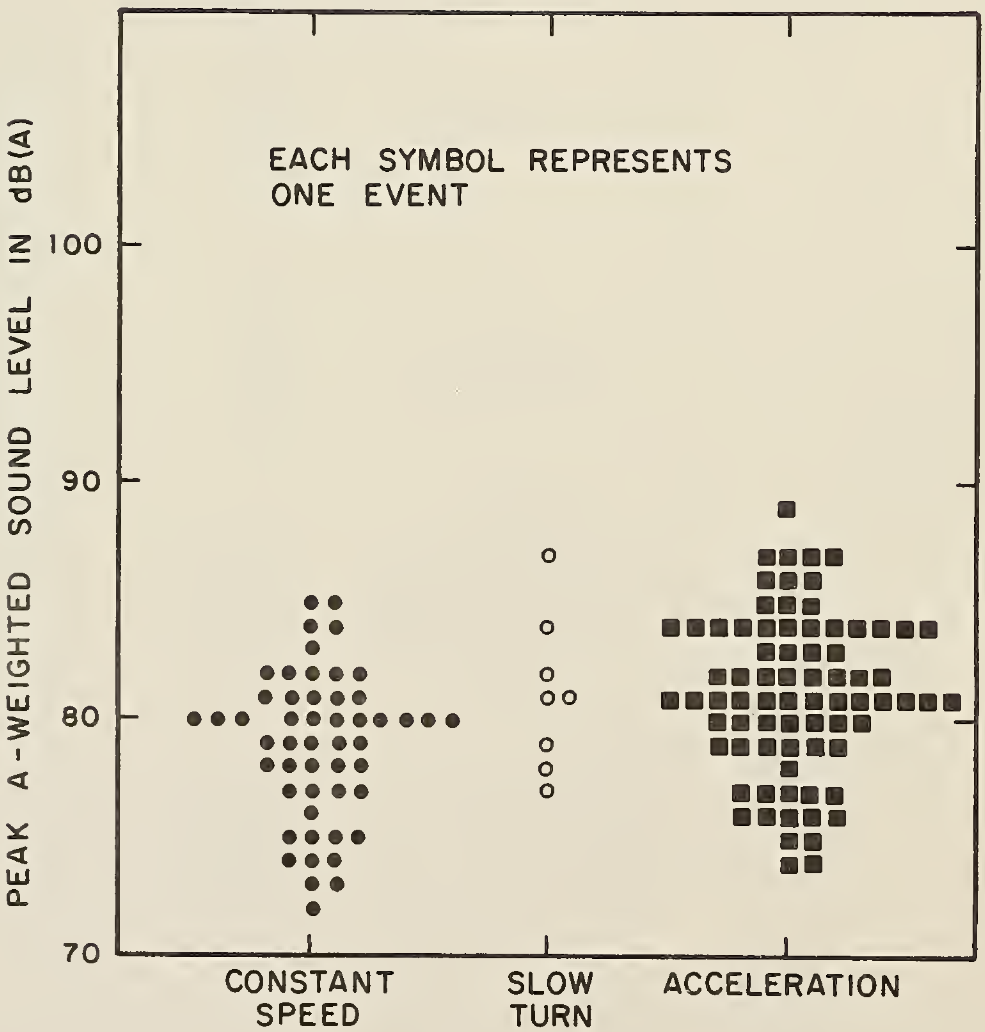

FIG.4b NOISE OF BOSTON SURFACE-STREET TRAFFIC GROUPED BY MODE OF OPERATION (DATA NORMALIZED TO 50 ft)

Figure 4b shows the distribution of noise levels for surface-street traffic grouped by mode of vehicle operation. The data show that the accelerating vehicles are several decibels noisier than those operating at constant speed.

One method of obtaining some indication of the future trends of motor vehicle noise levels is to utilize the model developed in Ref. 1* This model relates the average noise level observed in a metropolitan area to the density of vehicles and noise output of a single vehicle. [Very approximately, this "average noise level" can be expected to show the same behavior as the level that is exceeded 50% of the time. At the measurement site shown in Fig. 1, the level exceeded 50% of the time was 76 dB(A).] For U.S. metropolitan areas in general, Ref. 1 predicts an average annual increase in vehicle density of 6%, corresponding to an increase in average noise level of 0.3 decibel per year, and an average annual increase in vehicle noise output of 0.1 decibel per year, associated with a gradual increase in horsepower. On this basis the model predicts a composite increase in average noise level of 0.4 decibel per year, or an increase of 4 decibels in 10 years. To relate this increase to familiar situations, we note that the difference between a normal voice level and a raised voice level is approximately 6 decibels, and the difference between a raised voice level and a shouting voice level is approximately 12 decibels.

The model of Ref. 1 is concerned with *average* levels, whereas the data in Figs. 2 and 4 are for *peak* levels. On the basis of the projections in Ref. 1, the peak levels would increase

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*A list of references can be found at the end of this report.

only 0.1 dB/year, a practically insignificant amount. (Noise artification of new motor vehicles and noise limits for vehicles in use could result in a decrease rather than an increase in peak levels.) The frequency of occurrence of these peak levels depends on the rate of traffic flow.

This discussion suggests that even without preventive measures, neither the noise levels nor the peak noise levels of motor vehicle noise in a metropolitan area are expected to increase markedly. There will of course generally be a marked increase in noise levels when a formerly quiet area is penetrated by a major highway. The control of such noise levels where they do thus increase may require the imposition of vehicle noise regulations, roadway relocation, barriers, or enclosures.

C. Representative Construction Noise Levels

Noise levels associated with construction operations vary with the site and the scope of the project involved. A brief series of measurements was made to determine a sample of construction noise in the City of Boston. The measurements were made at several sites in the city; however, in the analysis all data have been normalized to a distance of 50 ft. The results are shown in Fig. 5. In addition, because little detailed information is available on construction noise levels, the frequency analyses of the data are given in Figs B-1, B-2 and B-3 in Appendix B.

A major component of construction noise is that associated with the exhaust and engine casing of engine-powered equipment. Equipment such as backhoes, crawlers, bulldozers, and cranes generally fluctuate load and rpm continually during normal operation. Examples of noise levels produced by three different backhoes while excavating are shown on Fig. 5.

The operable units of these machines may create additional noise, such as the squeal and clang of the bucket and halftracks. Figure 5 includes the noise levels produced during acceleration of two crane engines. Noise may also be created by the objects the crane is manipulating, such as reinforcing bars or a steel ball. Even when swinging a steel ball in demolition, however, the engine and exhaust systems are usually the controlling noise sources.

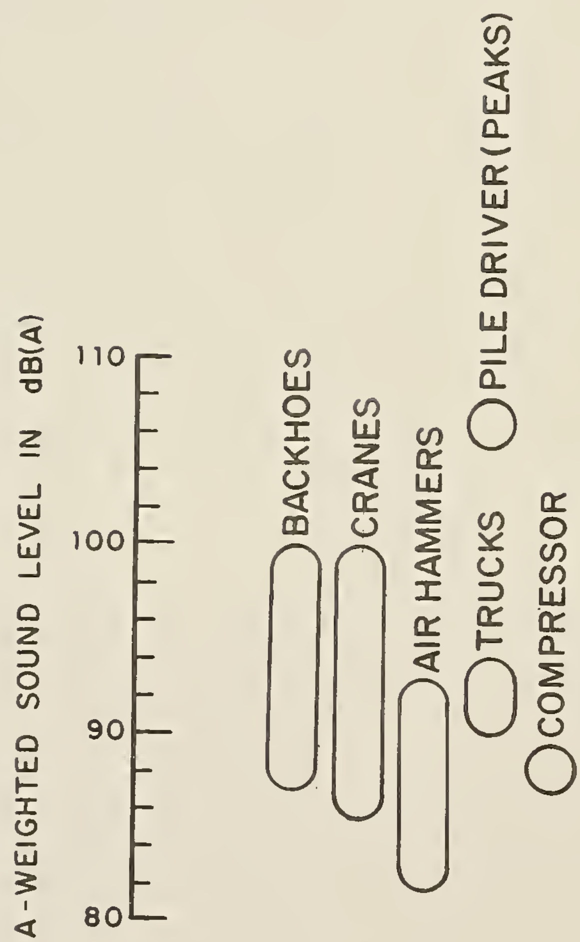


FIG.5 CONSTRUCTION SITE NOISE LEVELS (DATA NORMALIZED TO 50 FT)

Another family of equipment which produces a wide range of noises is pneumatic and steam driven tools. Significant noise levels occur when these tools come into contact with surfaces or objects on which they are working. A typical air hammer produces a series of sharp, repetitive blasts. This level usually drowns out the compressor noise, even though the compressor is accelerating above its idling level. Figure 5 presents the noise levels of an air hammer breaking an asphalt surface and rock base of a street, and the impact noise produced by a steam-driven pile driver.

Information on quieted construction equipment now commercially available is given in **the later section** on quieted equipment.

In addition to the noise created by specialized equipment, there are types of noise which can be found on nearly any construction site, such as noise from trucks, small finishing tools, saws, and drills. Figure 5 shows the noise levels created by trucks at two construction sites. Comparison of the truck noise levels with the noise levels of construction equipment indicates that the truck noise is comparable in level to the noise of many of the equipment sources. This observation emphasizes the need to control motor vehicle noise, even at construction sites.

III. CRITERIA AND STANDARDS

In developing a program for controlling community noise, it is convenient to distinguish among noise criteria, standards, and limits. Criteria are statements of the effects produced by various levels of exposure to noise, including consideration of such effects as speech interference, sleep interference, and hearing damage. Standards describe the noise environment considered acceptable in the community. Such standards represent long-term goals which a regulatory program may be designed to reach. Limits are specific rules established for individual noise sources. The limits involve not only a knowledge of the noise environments existing in the community but also the technological and economic limits of noise abatement and the important local social considerations. As a result of the application of the noise limits, the environment should approach the goals of the noise standards in a programmed fashion. Thus, the noise standards may be thought of as setting the community's policy towards the noise environment, while the noise limits are the specific means of implementing this policy.

It would be desirable if a clear relationship could be established between noise standards and limits, in order to state that a certain change in a specific limit would produce a corresponding improvement in the environment, thereby approaching the desired standard. Unfortunately, at present there is not such a clear relationship. It is possible (as with the model in Ref. 1) to develop a limited relationship between the average noise level and the densities and strengths of common noise sources. However, at present no detailed and

useful means exist for relating the characteristics of the many possible noise sources to the resulting composite noise heard in the community. Thus, it is necessary to adopt an empirical approach: to select standards on the basis of available criteria information, to establish limits for those sources that appear most important and/or most readily controllable, and to monitor the environment and observe how the enforcement of the limits helps to approach the standards. The standards also serve as guides for making planning decisions regarding the choices of land use in areas with certain expected noise environments. Thus, monitoring is an important part of the standard- and limit-setting process.

In the remainder of this section, we will be concerned with summarizing available information on criteria and establishing the community noise standards. The selection of specific noise limits for certain sources will be considered in the following sections.

A. Criteria: The Effects of Noise

1. Speech Interference

One of the most obvious effects of urban noise is interference with speech communication. Such interference usually involves a masking process. As a result of noise, a person may hear only a few or even none of the speech sounds necessary for satisfactory intelligibility. Also, noise of a certain level may mask some speech sounds but not others, depending on the talking level, particular speech sound, and relative frequency distributions of the sound and of the noise.

As shown in Appendix A, the A-weighted sound level correlates extremely well with other more complex measures of the speech interference of noise. Thus, it is convenient to summarize available information on speech interference in terms of the A-weighted sound level. One such summary is shown in Figure 6 [22]. The lines in this figure describe the maximum distances possible for satisfactory face-to-face communications at various speaking voice levels when the speaker and listener are in an open space (no nearby walls or other enclosures). The diagonal line furthest to the left is for speech at a normal speaking level; the parallel lines to the right of this line are for speech at raised, very loud, and shouting voice levels, respectively. Thus the Figure shows that face-to-face communications would be possible at distances up to 16 feet in the presence of a noise level of approximately 52 dB(A), and at a distance of 16 feet with a raised voice in the presence of a noise level of approximately 58 dB(A). The lines labeled "Expected Voice" and "Communicating Voice" reflect the observation that one tends to raise one's voice level when speaking in the presence of noise. If communications are not vital, the line labeled "Expected Voice" should be used to show the maximum distance at which communications are possible; if communications are vital (as in certain industrial and military situations) the line labeled "Communicating Voice" should be used to obtain the maximum distance.

The sound fields in rooms or other enclosed spaces do not behave as simply as assumed in the composition of Fig. 6. For comfortable listening to television and radio at typical speech levels, the indoor noise level should not exceed

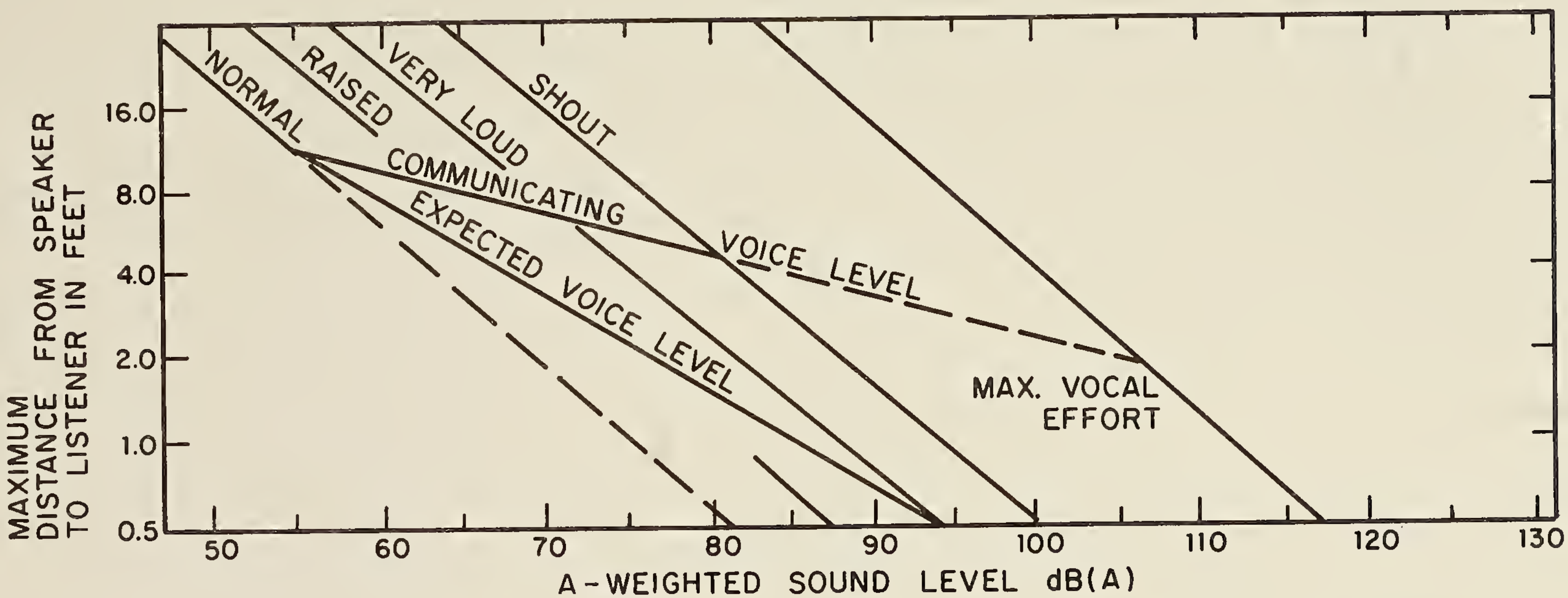


FIG.6 EFFECTS OF NOISE ON SPEECH INTERFERENCE (LINES INDICATE MAXIMUM SPEAKER-LISTENER DISTANCES FOR SATISFACTORY FACE-TO-FACE COMMUNICATION IN OPEN SPACES (SEE TEST); FROM REF.22)

approximately 40 to 45 dB(A) [24]. Since the noise reduction of a house with open windows is approximately 5 dB(A), the outside noise levels for comfortable television and radio listening inside should be no more than about 45 to 50 dB(A) with the windows open. These maximum outside levels may be increased by approximately 10 dB(A) if the windows are of conventional single-pane construction and are closed.

2. Sleep Interference

In one set of experiments sleeping subjects were exposed (several times each night) to a recording of truck noise played at a selected level [25]. It was found that there is a 5% probability of awakening the subject at the 40 dB(A) level and a 30% probability at the 70 dB(A) level. Some subjects awaken more than half the time at peak noise levels of 50 dB(A); others virtually never awaken, even at 75 dB(A). A more sensitive measure of disturbance is the change in sleep level. There is a 10% probability of a shift in sleep level at the 40 dB(A) noise level, and a 60% probability at the 70 dB(A) level [26].

Another set of experiments [27] showed that when continuous noise is at a level of 50 dB(A), falling asleep is a lengthy process (1 to 1-1/2 hours) and the intervals of deep sleep are fairly short (1 hour), followed, upon waking, by a sense of fatigue accompanied by palpitations. At 40 dB(A) it took 30 to 40 minutes for subjects to fall asleep, and there were longer periods of deep sleep, with no special feeling of tiredness upon awakening. The experimenters concluded that a noise level of 35 dB(A) could be considered a threshold for

optimum sleeping conditions, since at this level it took only 20 minutes to fall asleep, with periods of deep sleep lasting from 2 to 2 1/2 hours.

A third set of experiments [28] studied the sleep disturbance due to 3 types of traffic noise: (1) a control condition with no traffic [median level 48 dB(A)], (2) continuous noise of light traffic [median level 61 dB(A)], and (3) continuous noise of heavy traffic [median level 70 dB(A)]. Surprisingly, when compared to the control condition, the light traffic condition caused greater sleep disturbance than did heavy traffic, approximately doubling both the time required to fall asleep and the time before the onset of deep sleep. The heavy traffic condition produced results similar to those of the control condition. The suggested explanation for these results is associated with the very different characteristics of the peak-to-background noise levels of the two traffic conditions. Although the median level in the heavy traffic condition was 9 dB(A) greater than that of the light traffic condition, the heavy traffic time pattern was much steadier, that is, it contained fewer peak-background fluctuations than the light traffic time pattern. The subjects seemed to sleep better in the steady noise environment than in the fluctuating noise environment.

3. Physiological Effects

The most publicized physiological effect of noise is the cumulative loss of hearing acuity occurring after long-term exposure in high-level noise fields. Some indication of the noise levels related to this effect can be seen from

the limits set under the Walsh-Healey Public Contracts Act [29] and from limits recently extended under the Occupational Safety and Health Act [30]. These limits specify that workers should not be exposed to levels in excess of 90 dB(A) over an 8-hour working day. A 5-decibel increase is permitted for each halving of the exposure. A recent tentative proposal states that the noise levels during the non-working period of the day should be at least 15 dB(A) lower than the levels during the working period, in order to avoid additional contributions to the hearing damage [31].

Community noise levels rarely reach the limits set for occupational exposures under the Walsh-Healey Act. However, there is growing concern that exposure to urban noise levels may contribute to the loss of high-frequency acuity — a loss which was formerly considered part of a natural aging process. It has been reported that primitive African tribes who live in a background noise level of approximately 30 dB(A) do not experience such loss of high-frequency acuity. However, when such tribes move to a larger city their hearing abilities are impaired and the incidence of heart disease increases [32].

There has also been concern about other physiological effects associated with noise, such as dilation of pupils, flow of saliva and gastric juices, and cumulative effects resulting from lack of adequate deep sleep [33, 35, 37]. At present, little quantitative information is available about the importance of such effects.

To summarize the available information on the specific effects of urban noise, we quote from a recent survey [2]:

"*The average outdoor noise levels should not exceed 45 to 50 dB(A) for comfortable radio and TV listening with windows open (or 55 to 60 dB(A) with windows closed). To avoid sleep interference (not limited just to conscious awakening), the peak outdoor levels should not exceed 40 to 45 dB(A), corresponding approximately to mean indoor levels of 35 to 40 dB(A) with windows open; with ordinary windows closed, the outdoor levels may be permitted to increase to 50 to 55 dB(A). In addition, the peak-background noise structure is important, the more peaky pattern being the more likely to cause disturbance.*

The studies of physiological effects of noise bear on the establishment of an acceptable living environment only by setting an absolute upper limit on (continuous)*tolerable noise exposure, of the order of 80 to 85 dB(A), measured outdoors.*"

For further information on criteria, the reader is referred to Refs. 20 and 34, which contain several comprehensive summary papers on the effects of noise on man.

B. Standards: Long-Term Goals

A basic feature of almost any community noise situation is its time-varying nature. Temporal fluctuations may be considered to be short-term — as when a truck passes, or an aircraft flies overhead — or long term — as when the general level of activity decreases during the middle of the

night, making community noise levels significantly lower than those encountered during the middle of the day. In order to take these fluctuations into account in setting community noise standards, we recommend using a statistical description of the noise environment. Use of this format is becoming more common for describing community noise. It describes not only the noise level that would be acceptable "on the average," but also the noise levels that should not be ex- exceeded 10%, 25%, or other fractions of the total day.

The discussion of criteria provided some idea of the noise levels considered psychologically and physiologically acceptable. A recent draft Policy Circular of the U. S. Department of Housing and Urban Development contains interim noise standards for residential noise exposures [36], and we recommend that the City of Boston adopt interim community noise standards that are derived from these HUD standards.

Figures 7a and 7b give the proposed Boston interim noise standards for residential and for commercial and industrial land uses. These standards apply to a 24-hour sample of noise. Noise environments are divided into three categories. In order for the environment to be considered "Acceptable" for the land use under consideration, the results of an analysis of the 24-hour sample must lie on the left-hand side of Fig. 7a (for residential land use) or Fig. 7b (for commercial or industrial land use). If the results exceed these limits, the noise levels must be reduced. In general this reduction will involve modifying the sources of noise.

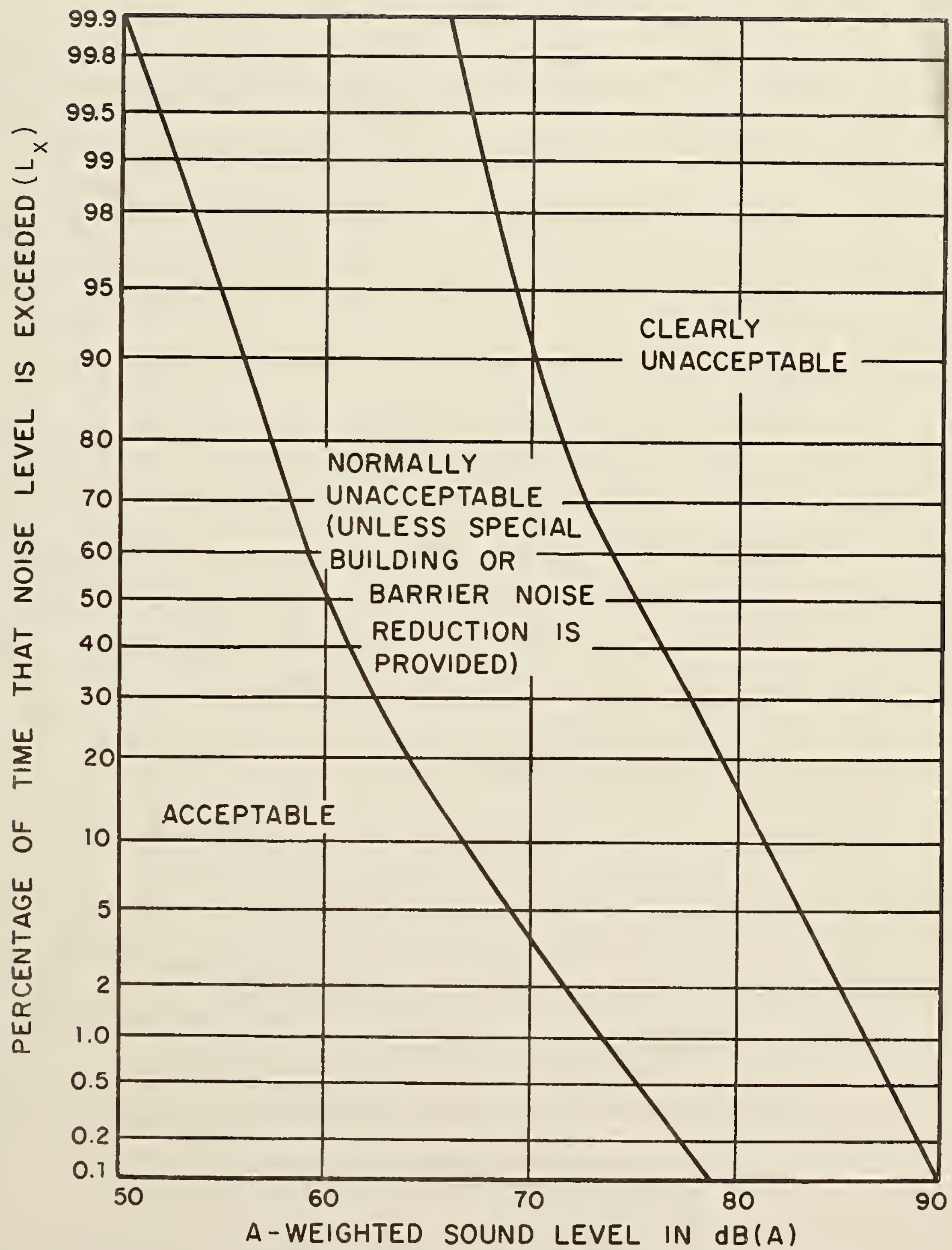


FIG.7a PROPOSED INTERIM COMMUNITY NOISE STANDARDS FOR RESIDENTIAL LAND USES IN BOSTON

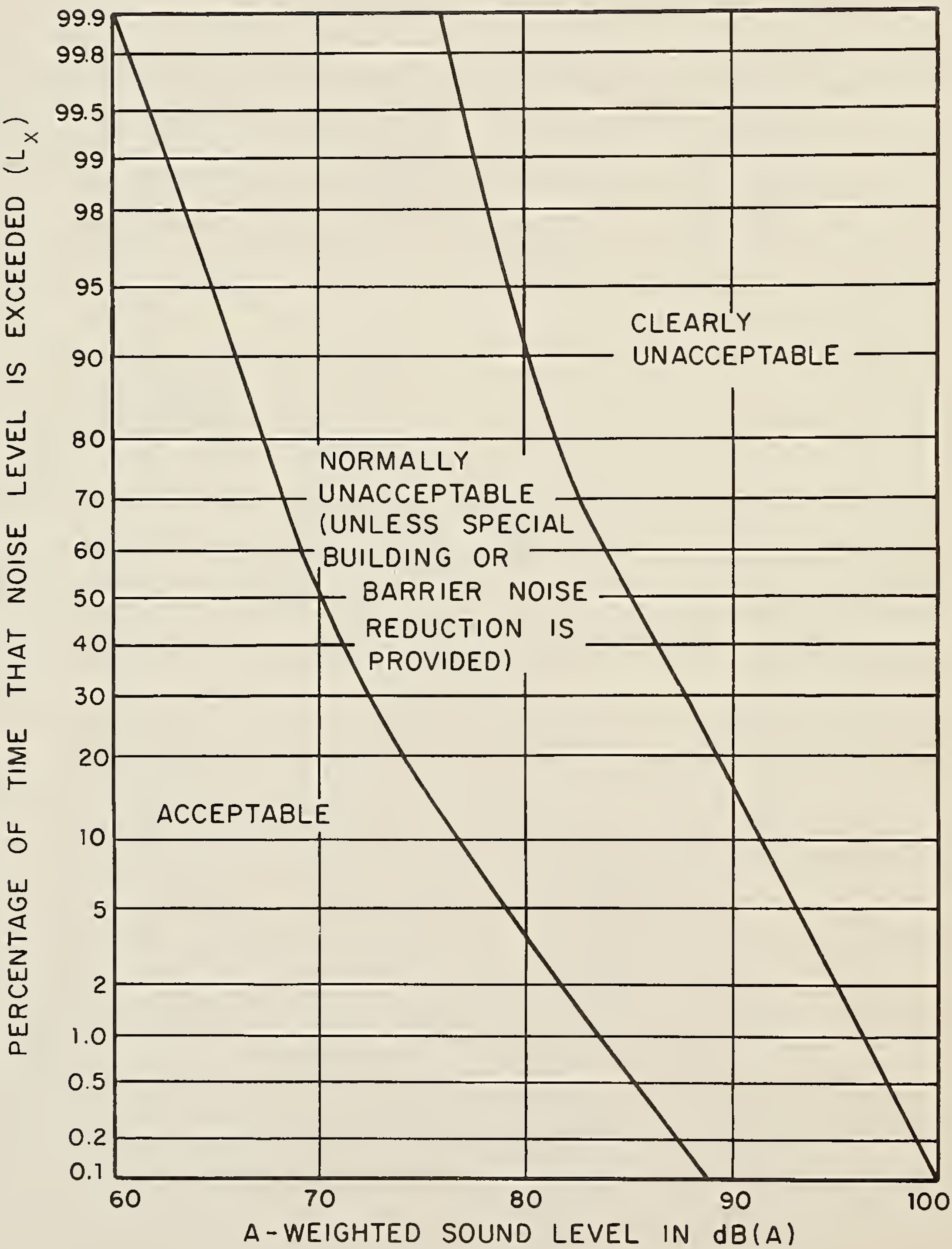


FIG.7b PROPOSED INTERIM COMMUNITY NOISE STANDARDS FOR COMMERCIAL AND INDUSTRIAL LAND USES IN BOSTON

In the special case when the results lie in the portions of Figs. 7a or 7b labeled "Normally Unacceptable", and no further reduction in the noise levels can be feasibly achieved by source modification, the environment may be considered acceptable for indoor activities if noise reduction is provided either by the specifications of the building (such as fixed double windows) or by a noise barrier.

The proposed interim community noise standards in Figs. 7a and 7b may be compared with those proposed to the Highway Research Board (HRB) for highway noise in residential areas [3]. For daytime noise these proposals state that in residential areas the level exceeded 50% of the time should not exceed 50 dB(A) and that the level exceeded 10% of the time should not exceed 56 dB(A). Nighttime noise levels are 5 dB(A) lower than the daytime limits. A comparison with Figs. 7a and 7b shows that these proposed standards are considerably more stringent than the proposed Boston community noise standards. For example, the level recommended for daytime highway noise situations is about 10 dB(A) lower than the L_{50} level indicated by the curve between the "Acceptable" and "Normally Unacceptable" regions on Fig. 7a. This difference is due to the fact that the proposed Boston interim standards are descriptions of <u>acceptable</u> situations, whereas the HRB and foreign standards are descriptions of <u>highly desirable</u> situations. As progress is made in reducing community noise levels, the Boston interim standards should be upgraded to approach the highly desirable situations.

The proposed interim community noise standards may be compared with actual data. Figures 8, 9, and 10 present noise level distributions measured at locations in Boston, New Orleans, and Seattle. The comparison with Fig. 7a indicates that, even though the proposed interim standards are not stringent enough to represent a highly desirable situation, existing levels are well in excess of the levels in the "Acceptable" region of the proposed standard for residential land use, and often in excess of the "Acceptable" levels for commercial or industrial land use.

Additional comparisons may be made with community noise standards recommended in other countries. Table 8 lists some of the standards recommended for use in Switzerland [6], Scandinavia [7], and the United Kingdom [8].

1. Exposure to Traffic Noise

The results of interview surveys (such as those reported in the previous section, or Refs. 8 and 9) consistently show that surface motor vehicles are the most common source of annoyance with noise. Methods are available for estimating this noise from such information as vehicle types, flow rates, and roadway configuration [3]. We can compare these noise estimates with the interim standards proposed in Fig. 7a to obtain another measure of the extent of the noise problem.

An approximate model of traffic flow within the City of Boston was developed from data contained in Refs. 10, 11, and 12. Since most of the information in these references

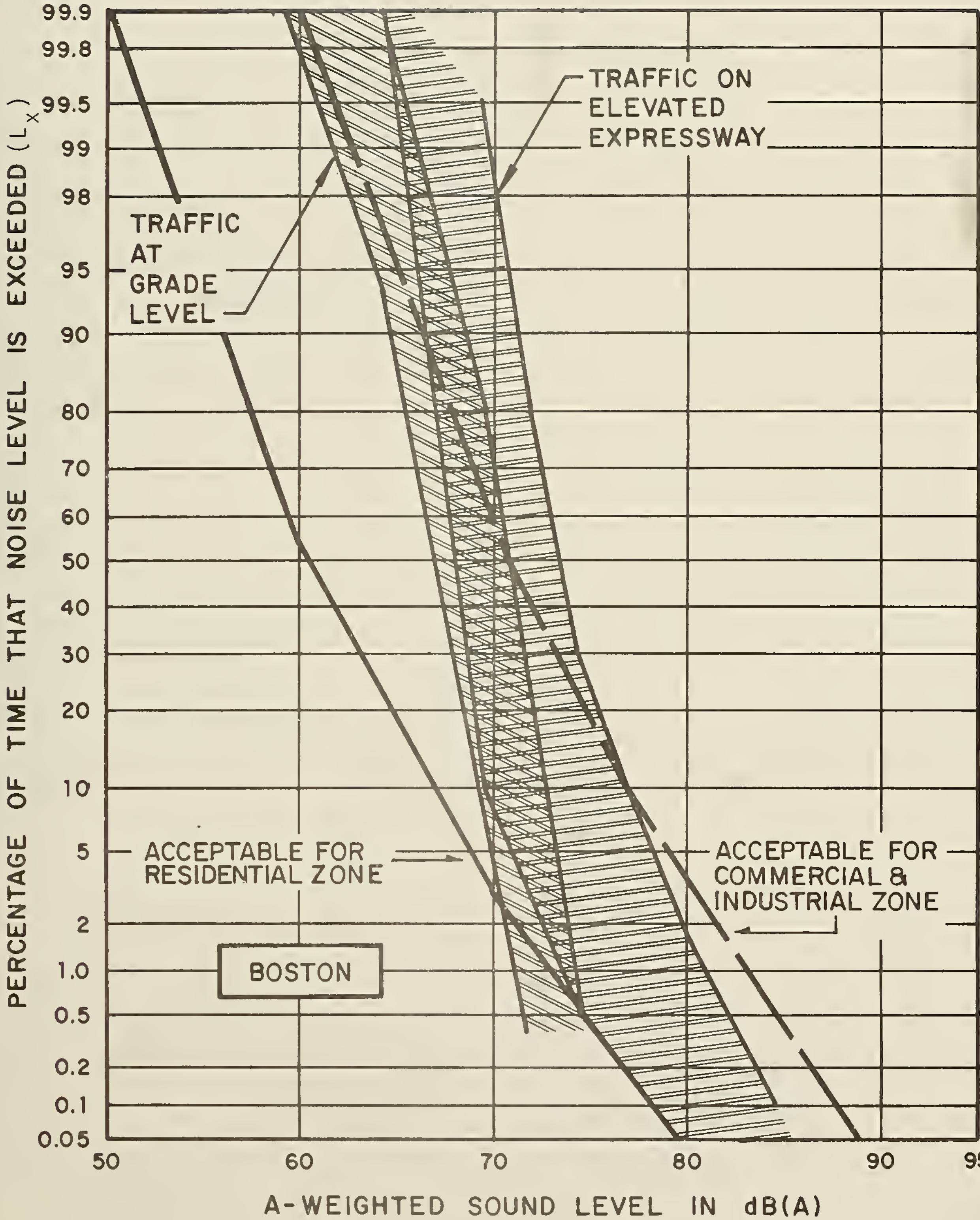


FIG. 8 REPRESENTATIVE URBAN NOISE LEVELS; BOSTON (Near Southeast Expressway; 1:00 P.M. To 5:00 P.M.; Daily Traffic Count = 76,000 Vehicles; From Ref.4)

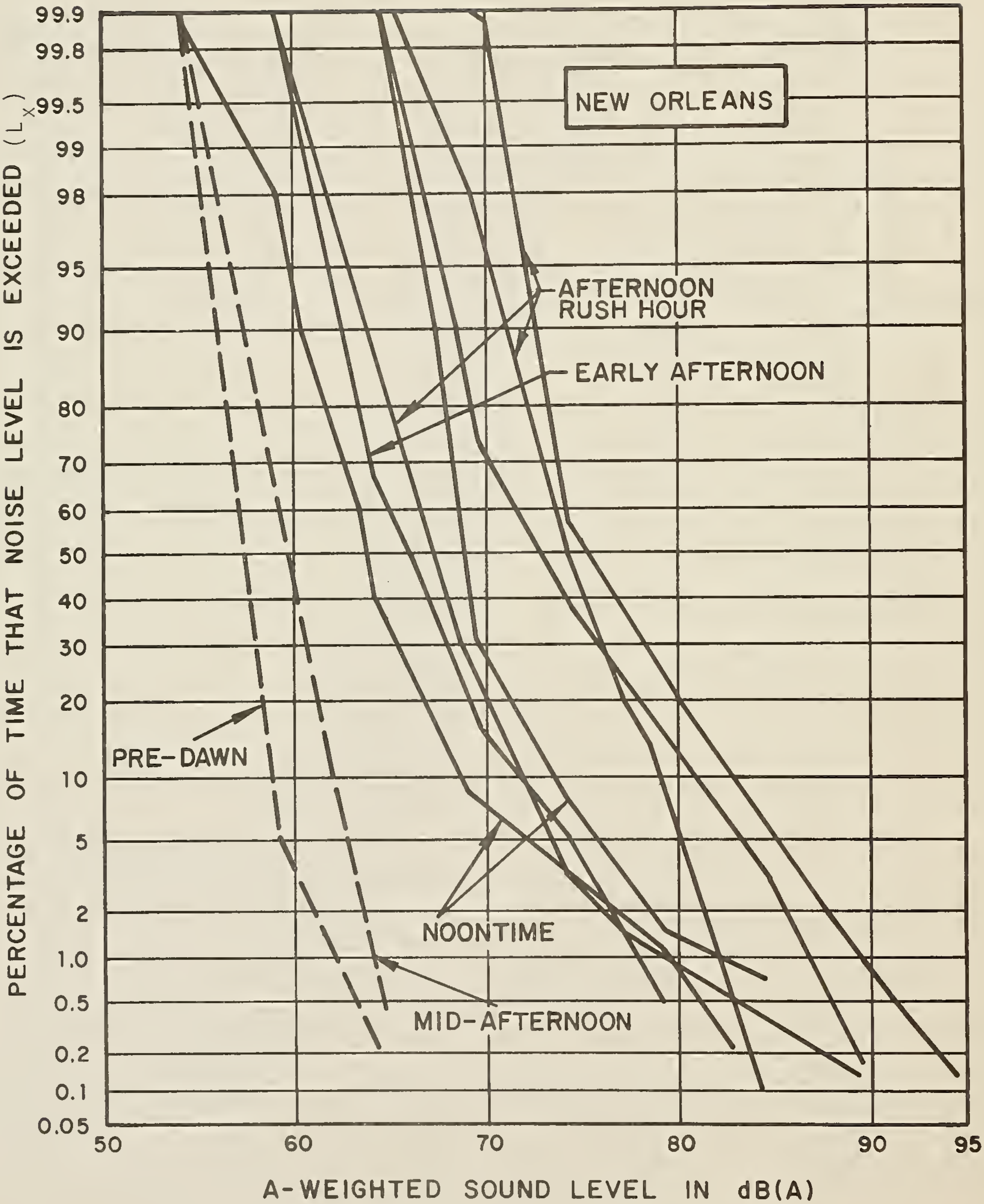
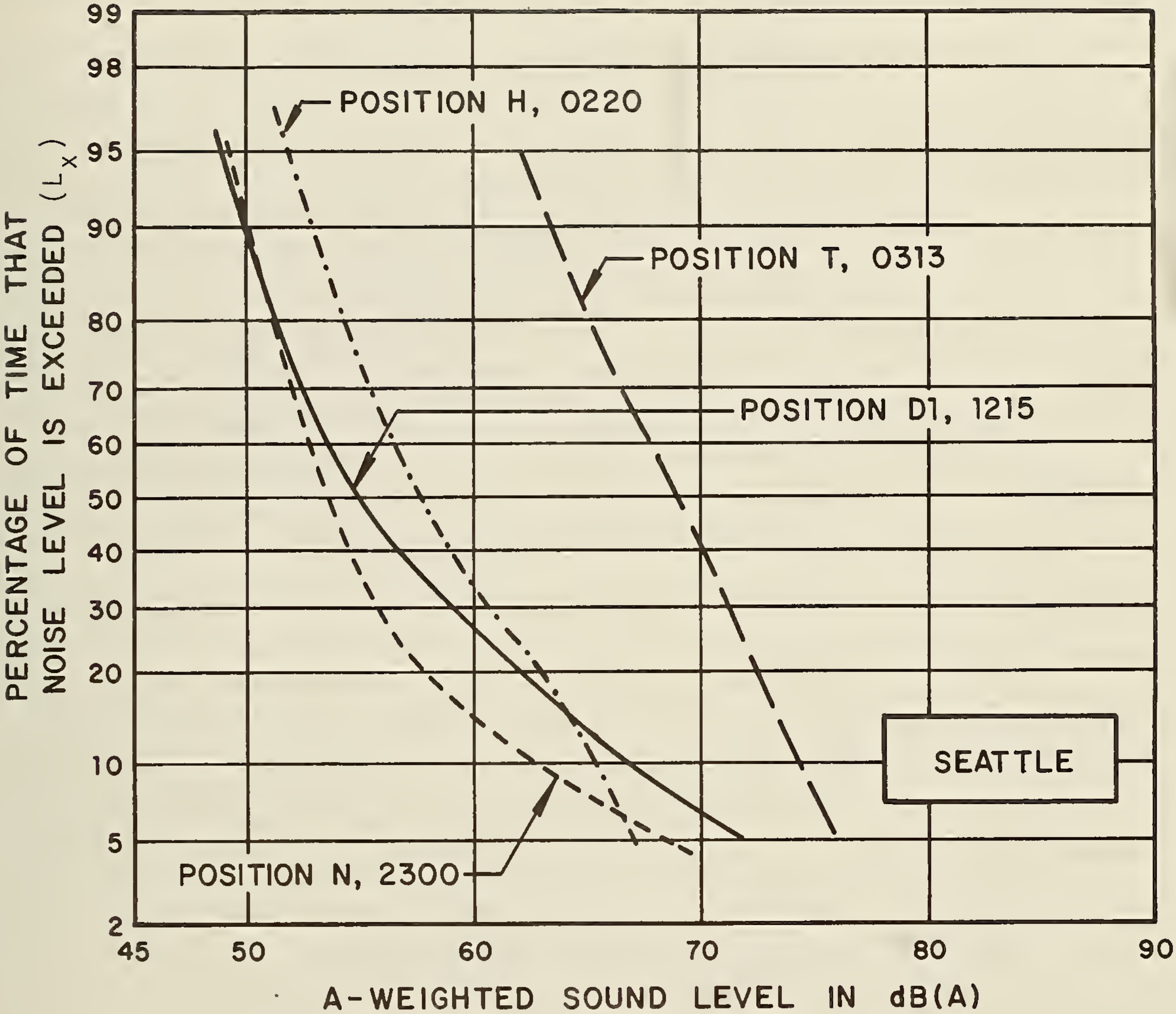


FIG.9 REPRESENTATIVE URBAN NOISE LEVELS; NEW ORLEANS (Jackson Square; From Ref.4)



POSITION D1	RESIDENTIAL, ON RIDGE LINE OF HILL, 200FT FROM MILITARY RD; BOEING FIELD PLANT II AND HIGHWAY VISIBLE
POSITION H	RESIDENTIAL, NEXT TO SCHOOL; OVERLOOKS BOEING FIELD, PLANT II AND HIGHWAY
POSITION N	RESIDENTIAL NEXT TO CHURCH; SHIELDED FROM NEARBY ARTERY BUT OVERLOOKS DISTANT HIGHWAY AND BOEING FIELD
POSITION T	RESIDENTIAL, SOUTH BOEING FIELD AND HIGHWAY VISIBLE (NO APPARENT REASON WHY LEVELS SO HIGH)

FIG. 10 REPRESENTATIVE SUBURBAN NOISE LEVELS; SEATTLE (Near Boeing Field; From Ref.5)

TABLE 8: RECOMMENDED COMMUNITY NOISE STANDARDS IN SEVERAL FOREIGN COUNTRIES [6,7, 8].
A-Weighted Sound Levels in dB (A)

Switzerland (1963)	Background Noise (L_{50}?)		Highest Peaks (L_1?)	
	Day	Night	Day	Night
Residential	55	45	70	65
Commercial	60	50	75	65
Hospitals	45	35	55	55

SCANDINAVIA (1967): $L_{50}{}^{*} \leq$ 59 for road traffic, 24-hour average

UNITED KINGDOM (1963): $L_{10}{}^{**} \leq$ 30-35 at night indoors (approx. 40-50 outdoors)

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*i.e. Level in dB(A) which is exceeded 50% of the time
**i.e. Level in dB(A) which is exceeded 10% of the time

originated from studies made in 1964 and 1965, other more recent information [13] on specific intersections was used to determine general trends that in turn were used to update the 1964/65 data. Car-to-truck ratios were also predicted using generalizations of the specific intersection data.

Two general statements about traffic noise are pertinent. First, with typical urban stop-and-go traffic (number of trucks ranging from 5% to 20% of the total number of vehicles), the noise levels will be controlled by the trucks. Second, freely-flowing traffic of these mixes produces significantly less noise [approximately 10 dB(A)] than stop-and-go traffic of the same volume.

Due to the availability of traffic flow information on the downtown Boston area (from Fort Point Channel west to Riverway, from the Charles River south to Dudley or Southampton Street), our first study concentrated on this area.

In the downtown Boston area, virtually every location is subject to a sufficient volume of *stop-and-go traffic* (owing to traffic congestion, stop signs, or signalized intersections) or a much greater volume of *freely-flowing traffic* (turnpike, expressways, etc.) to result in estimated "Clearly Unacceptable" noise levels at locations facing a street, expressway, etc. Locations shielded from roadways will experience less noise to a varying degree. However, the majority of traffic noise sources in downtown Boston would have to be quieted by over 20 dB(A) to result in "Acceptable" levels for the entire area. Noise levels in the area would be reduced by about

10 dB(A) if all stop-and-go traffic became 20 mph traffic. This points to the desirability of such approaches as one-way streets or phased traffic lights that would facilitate freely-flowing traffic on major arteries.

The problem of suburban traffic noise was also considered. Here freely flowing 30 mph traffic with a normal 8% truck mix was assumed. To achieve "Acceptable" levels at a residence 50 ft from the roadway, the traffic volume must be below 400 vehicles per hour. This is only 6 or 7 vehicles per minute. Virtually every through connecting street in suburban Boston has a traffic volume equal to or exceeding this rate. The needed vehicle noise level reductions vary according to the flow, but typical reductions of 5 to 15 dB(A) would be needed for the suburban cases.

TABLE 9. SUMMARY OF COMPARISONS BETWEEN COMMUNITY NOISE STANDARDS

%Time Level is Exceeded	Location	Proposed Standard (Fig. 7)	Standard and Statements of Others
50%	in residential areas	60 dB(A)	55-60 dB(A) for comfortable listening (windows closed) [2] 45-50 dB(A) [3] 45-55 dB(A) [6] 59 dB(A) (double windows closed) [7]
50%	in commercial areas	70 dB(A)	50-60 dB(A) [6]
10%	in residential areas	67 dB(A)	51-56 dB(A) [3] 40-50 dB(A) [8]
1%	in residential areas	74 dB(A)	50-55 dB(A) to avoid sleep interference (windows closed) [2] 65-70 dB(A) [6]
1%	in commercial areas	84 dB(A)	65-75 dB(A) [6]

IV. ELEMENTS OF A REGULATORY PROGRAM

A. Approaches for Noise Abatement

Several different approaches can be considered for the abatement of exterior noise. The selection of an appropriate approach depends not only on the particular sources of concern but also on the available resources and the local attitudes and situation. In this section we will first discuss certain approaches and will then describe the approach that we believe is most appropriate for the City of Boston.

It is sometimes stated that an effective approach for urban noise abatement is based on educating the citizens to "Think Quiet". Such an approach utilizes education, persuasion, and the tools of public relations. It relies on active support from the various levels of government, civic leaders and groups, and the press. It may also entail demonstration projects that show how quiet equipment can be obtained or operated.

The City of Memphis is often cited as an example of the effectiveness of this approach. In 1938 Memphis adopted a regulation prohibiting "any unreasonably loud, disturbing and unnecessary noise". For two years following there was an extensive education effort, and the police issued warnings but no fines. After 1940 fines were levied, usually $5 for noisy mufflers and $3 for horn-blowing, and the educational effort was intensified to convince the public that the purpose of the fines was to reduce the noise rather than to raise money. Within another year the program was considered a success. The City won awards from the National Noise Abatement Council as "The Nation's Quietest City" each year that the award was made, from 1945 to 1960.

An abatement program based on the approach of education and persuasion may sound somewhat appealing at first thought, and indeed elements of education and persuasion certainly must form adjuncts of any abatement program. However, we believe that an abatement program based primarily on such measures would not be successful in the City of Boston today, for several reasons. First, the scanty literature available suggests that the Memphis program was concerned largely with faulty mufflers and excessive horn-blowing. Thus the program was not addressed to industrial or construction noise sources or rail vehicles. The complaint records for the City of Boston suggest strongly that such non-automotive noise sources must be included in an abatement program. Second, it is highly probable that the legality of a new ordinance modelled on the Memphis ordinance might be challenged today. In our opinion such a nonquantitative ordinance would not be found adequate in any court test. Third, duties and pressures imposed on the Boston Police force today are undoubtedly more varied and demanding than those felt by the Memphis Police force thirty years ago. We suggest that it is unlikely that Boston police would be able to assume the additional responsibility of warning the operators of offending motor vehicles.

A quite different approach to noise abatement is the establishment and enforcement of quantitative noise limits for specific sources. In general, we advocate this approach, although we would stress that the choice of sources to be regulated must be made with considerable care. Because motor vehicles are consistently observed to be the most common exterior noise source of annoyance, an exterior noise abatement program should include objective limits for motor vehicles in use. Several cities, states, and foreign countries have established objective noise

limits for motor vehicles in use. Figure 11 presents a comparison of noise limits set for one important vehicle situation, heavy trucks at speeds greater than 35 miles per hour. However, an examination of the experience encountered with these motor vehicle regulations indicates that, in general, enforcement is almost nonexistent. A notable exception is the State of California, where the California Highway Patrol enforces the noise limits. The Highway Patrol generally restricts enforcement to freely-flowing highway traffic. Of more than 600,000 vehicles measured during a 12-month period, 2,861 violators were found. Three-quarters of the violators were trucks moving at speeds greater than 35 miles per hour. 1.2% of all trucks checked, 2% of all motorcycles checked, and less than 0.1% of all autos checked were violators.

Several factors contribute to the success of the California vehicle noise abatement program. First, the regulations and supplementary procedures are well-written and unambiguous. Second, a special, trained enforcement crew has been provided. Third, the State of California has worked closely with vehicle manufacturers and trucking firms to explain the objectives and workings of the program, and has received their cooperation.

We recommend that the City of Boston follow a noise abatement approach that is based primarily on the establishment and enforcement of quantitative noise regulations for specific sources or situations. However, even though motor vehicles are the most widespread source of noise annoyance, we do *not* recommend that the City adopt a qualitative regulation controlling vehicle noise *in use* at this time, because of the special personnel, training, and facilities required to enforce such a regulation

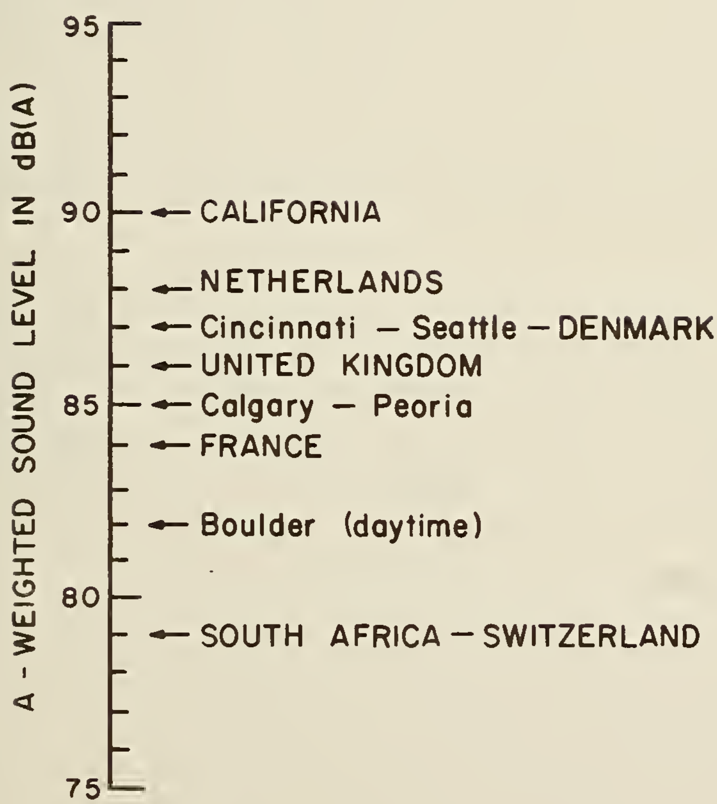

FIG. 11 NOISE LIMITS FOR HEAVY TRUCKS AT HIGHWAY CRUISING SPEEDS
(LIMITS CONVERTED TO 50 FT.)

(such regulations might better be introduced at State levels). Instead, we recommend that the City take advantage of the noise limits already established in other areas on vehicles *for sale*, and plan to adopt limits for vehicles in use at some time in the future, perhaps together with other cities or as part of a statewide program.

We recommend that the City adopt at this time noise regulations limiting the noise from construction activities; a general regulation limiting the noise at zoning or property lines of residential, commercial, and industrial sites; noise regulations limiting the noise from new motor vehicles for sale or lease; and powered outdoor equipment. Specific recommendations for these regulations are given later herein.

In the previous section we presented certain proposed community noise standards and discussed the general information on which these standards or long-term goals were based. In the proposed regulations, we will present noise limits for specific locations and for specific sources. The selection of the limits on specific sources is made on two general bases. The first basis is the requirement that the sources make full use of available control technology. The second basis sets more stringent limits, anticipating that manufacturers will be able to modify sources to produce less noise in the future. Thus, the noise source limits in this section are given in schedule form, where the initial limits are intended to eliminate sources that do not represent good current practice, while the future limits are intended to encourage manufacturers to design noise control into their devices. We believe that this stepwise procedure is an appropriate way of approaching the long-term noise standards for urban environmental quality.

We also emphasize the desirability of adopting initial limits that have been adopted by other cities or states. Thus we recommend adopting the same vehicle-for-sale limits that are now in force in the State of California, and zoning and property line noise limits pioneered by the City of Chicago, and also in force in cities such as Columbus, Dallas, Dayton, Miami, Minneapolis, Peoria and Tucson. This procedure provides additional weight to the feasibility of the initial noise limits.

B. Staffing

It is axiomatic that the establishment of quantitative regulations is only one step in the development of an effective abatement program. Another essential step is the competent and consistent enforcement of such regulations. This enforcement will depend on the availability of properly trained personnel with adequate measurement equipment.

The regulatory measures recommended earlier in this section represent a first-year program, and are designed to control those noise situations that are of major concern to the City and that can be readily controlled at this time. The staffing and equipment recommendations given here are intended to be consonant with the recommended regulatory measures. As further regulatory measures are added to the program, the need for additional staffing and equipment will become apparent.

The recommended regulatory measures are concerned with the noise situations summarized in Table 10. Estimated levels of technical effort involved in field measurement, preparation of evidence, liaison with other City and State agencies, and related tasks are also given in the Table. The estimated manpower required totals two men. We recommend that these two engineering staff members be at significantly different levels, and sample job descriptions for these men are given in Table 11. The relatively large salary range suggested for the Environmental Acoustics Engineer is intended to cover the

TABLE 10

Noise Situations Covered by Recommended Regulatory Measures

Situation	Estimated Level of Technical Manpower Required
Zoning districts (residential, commercial, industrial)	1 man (emphasis on residential areas)
Construction sites	1/2 man
Surface motor vehicles (new vehicles for sale, horns) and powered equipment	1/2 man
	2 men

TABLE 11

Job Descriptions for Engineering Staff

Title: Engineer, Environmental Acoustics

Position Reports to: Executive Director, Boston Air Pollution Control Commission

Recommended Salary Range: $11,000 to $16,000

Normal Qualifications:

Education: BS in Electrical Engineering, Mechanical Engineering or Physics. Preferably will have completed courses in several of the following subjects:

Acoustics
Speech and Hearing
Basic Vibrations
Wave Propagation
Structural Vibrations

Experience: Over 4 years engineering experience with emphasis on sound and vibration measurement, analysis, and control. Should be familiar with general community noise criteria. Should have worked with sound and vibration measurement instruments including:

Sound Level Meters
Vibration Meters
Impact Noise Analyzers
Recorders & Plotters
Wave Analyzers

Primary Responsibility

Under general supervision will plan, conduct, and supervise field measurements of sound and vibrations with the objective of gathering valid data to be used to enforce the noise regulations of the Boston Air Pollution Control Commission. He will work with those in violation of the law to obtain voluntary compliance but when this fails he will supply sufficient technical data to seek compliance through the legal process. He must be able to qualify as an expert witness in the event he is called upon to testify in a legal proceeding as to the validity and significance of the data collected by him or under his supervision.

TABLE 11 *(Continued)*

Title: Engineering Assistant, Environmental Acoustics

Position Reports to: Engineer, Environmental Acoustics

Recommended Salary Range: $8,000 to $10,000

Normal Qualifactions:

Education: Associates Degree in Electrical or Mechanical Engineering

Experience: Should have worked with sound and vibration measurement instruments including:

Sound Level Meters
Vibration Meters
Impact Noise Analyzers
Recorders & Plotters
Wave Analyzers

Primary Responsibility

Under direct supervision of the engineer will conduct field measurements and analysis of sound and vibrations with the objective of gathering valid data to be used to enforce the noise regulations of the Boston Air Pollution Control Commission. He must be able to qualify as an expert witness on the subject of sound and vibration measurements in the event he is called upon to testify in a legal proceeding.

range of pertinent experience of applicants. Even if applicants are found who have considerable pertinent experience, however, we believe that some provision should be made for additional specialized training in such areas as fundamentals of mechanical equipment noise control, requirements for legal adequacy of acoustical data, and the interpretation of community noise criteria.

C. Equipment

We recommend that the Boston Air Pollution Control Commission have available a set of basic acoustical measuring instruments which will permit making all the measurements required by the proposed regulations.

Three general categories of instruments will be needed: (1) hand-held monitoring or quick surveying meters for discerning the presence of a problem; (2) precision sound level meters for accurate measurement of dB(A); and (3) octave band analysis equipment for measurement under the zoning noise regulations. In addition, there must be some accessories (tripod, wind meter, carrying case, etc.) and spares (mostly microphones).

Specific recommendations regarding the exact instrument set have been communicated to the Commission under separate cover.

D. Current Status of Statutes Affecting Noise Control

1. General Laws

The Commonwealth, through enabling statutes in the General Laws, has passed to local City authority the right to undertake noise control. The exact nature of the responsibility is not delineated nor are standards set, but the right to initiate regulation and control by the City is made clear (see Table 12).

2. Ordinance Assigning Noise Control to Air Pollution Control Commission

A recent Boston City Ordinance has acknowledged both the need for local responsibility and the lack of clear authority to control noise. Accordingly, the new Ordinance directs new and expanded authority for noise control into the hands of the Boston City Air Pollution Control Commission. Prior rather specific noise prohibitions in past Ordinances have been superseded by a generalized prohibition of "unreasonably loud or disturbing noise" which is subsequently defined in a generalized way (see Table 13).

3. Ordinance Defining Commission Powers

The scope of responsibility, authority and regulatory powers of the City of Boston Air Pollution Commission have been previously established in a general way by City Ordinance (see Table 14a) and State enabling legislation via the General Laws (see Table 14b).

4. Prior Noise Ordinances

Some guidance for Boston City noise regulation can be taken from a formerly applicable set of noise prohibitions and penalties contained in the Ordinances which were in effect until the recent reallocation of noise control responsibility (see Table 15).

5. Noise Control in Current Zoning Code

The Zoning Code of the City can be a significant tool in applying certain types of realistic noise control regulations in the future. Table 16 indicates where noise regulations now appear and where clarification, standards, or reference to noise regulations might apply in the future. The structure of the Code lends itself to building a useful and practical system for noise control in the City since noise standards could be set for each class of zone.

TABLE 12

EXCERPTS FROM GENERAL LAWS OF THE COMMONWEALTH RE NOISE ABATEMENT*

General Law 40:21 (22) (1969): "Cities...may regulate noise from whatever source including auto horns and auto noise."

General Law 40:22 (1949-68): "Except as noted in G.L. 90.8, 85.2, 89.8, City Aldermen may...regulate...carriages...."

General Law 90:16-20 (1961-68): "...emission of excessive noise from a muffler is prohibited."

General Law 90:16-20 (1961-1968): "A fine of $20 min, $100 max [may be imposed]...for excessive noise...from an exhaust system...."

General Law 40:21 (through 1965): "Unless otherwise specified, violations of...city regulations are punishable by a fine of $50 max."

*Extracted verbatim from "Compendium of Environmental Legislation", Comm. of Mass., Office of Comprehensive Health Planning, June, 1970.

TABLE 13

EXCERPTS FROM CITY OF BOSTON ORDINANCES PLACING NOISE CONTROL UNDER THE AIR POLLUTION CONTROL COMMISSION

Ordinance of March 16, 1970 (Approved April 2, 1970)

Places responsibility for noise regulation in hands of Boston Air Pollution Control Commission.

Whereas	– "...noise...on the increase...."
	– "...noise disturbs the peace, interferes with... enjoyment of life...endangers public health...."
	– "...no public agency...charged with responsibility for monitoring and abating...noise...."
	– "...noise and air pollution...overlapping...."
Section 1: Therefore	– "...the Revised through 1969 Ordinances *re* responsibility of Air Pollution Control Commission are amended...."
	– "...Air Pollution Control Commission shall...investigate, control and abate noise...and...adopt noise level standards and promulgate regulations providing that no...unreasonable noise [may be made] unless permit [is] obtained from the commission."
	– "...Commission shall...produce documents relevant to its work and compel...testimony of witnesses...."

TABLE 13 *(Continued)*

<u>Section 2</u>: Chapter 29. Section 97 of the City's Revised Ordinances (prohibiting unnecessary noise) deleted.

Following inserted in place of above:

- "No person shall make...any unreasonably loud or disturbing noise...In absence of applicable...standard or regulation...any noise plainly audible at... 300 ft shall be presumed to be unreasonably loud and disturbing, but such presumption shall be rebuttable".

TABLE 14a

SUMMARY OF ORDINANCE OF CITY OF BOSTON ESTABLISHING AIR POLLUTION CONTROL COMMISSION

<u>Ordinance of 1968</u> (Cited in 1969 cumulative Supplement)

<u>Ch. 15 (of 1969 Supplement)</u>: Revises Health Department

<u>Section 1</u>: – Renames Health Department to "Department of Health and Hospitals" (refers to Sec. 7, Ch. 4 of the General Laws).

<u>Section 2</u>: – Establishes Air Pollution Control Commission
- within Department of Health and Hospitals
- includes Commissioner of Health and two members appointed by mayor (3 year terms, unpaid)
- not controlled by, but reports through Board of Health and Hospitals
- Jurisdiction as per Sec. 31C of Chap. 111 of the General Laws

TABLE 14b

SUMMARY OF BASIC ENABLING LEGISLATION OF COMMONWEALTH

The Law Concerning Air Pollution Control and Adoption of Regulations By Local Boards of Health

Section 31C of Chapter 111, General Laws.

Inserted by Chapter 672 of the Acts of 1954
Amended by Chapter 483 of the Acts of 1963
Amended by Chapter 841 of the Acts of 1970

A board of health, or other legal authority constituted for such purpose by vote of the town or city council shall have jurisdiction to regulate and control atmospheric pollution, including, but not limited to, the emission of smoke, particulate matter, soot, cinders, ashes, toxic and radioactive substances, fumes, vapors, gases, industrial odors and dusts as may arise within its bounds and which constitutes a nuisance, a danger to the public health, or impair the public comfort and convenience.

Said board of health or other legal authority, subject to the approval of the department of public health, may from time to time adopt reasonable rules and regulations for the control of atmospheric pollution. Before the board of health or other legal authority submits such rules and regulations to the department for approval, such board or other legal authority shall hold a public hearing thereon, of which notice shall be given by publication for one day in each of two successive weeks in a newspaper published in the town, the first publication to be at least fourteen days prior to the date of the hearing, or if no newspaper is published in such town, by posting a copy of such notice in a public place therein. Said rules and regulations, when approved by the department, and

TABLE 14b *(Continued)*

after publication in a newspaper published in the town, or, if no newspaper is published in such town, after posting a copy in a public place, shall have the force of law.

The department shall advise the board or other legal authority in all matters of atmospheric pollution. The department, may, upon request of the board of health or other legal authority of a town adversely affected by atmospheric pollution arising in another town, after a hearing to all parties interested, assume joint jurisdiction to regulate or control such cause of atmospheric pollution and may exercise all powers of the local board of health or other legal authority under provisions of the General Laws or any special laws.

Whoever violates any order, rule or regulation promulgated or adopted under the provisions of this section shall be punished, for the first offense, by a fine of not less than fifty nor more than one hundred dollars and for a subsequent offense, by a fine of not less than two hundred dollars nor more than five hundred dollars. For the purpose of this paragraph each day or part thereof of violation of such an order, rule or regulation whether such violation be continuous or intermittent, shall be construed as a separate and succeeding offense.

Rules and regulations promulgated or adopted under the provisions of this section shall be enforced by said board of health or other legal authority either of which may delegate the power to enforce specific regulations to other agencies or departments of the same city or town. The superior court shall have jurisdiction in equity to enforce such rules and regulations and may restrain by injunction any violation thereof.

TABLE 15

EXCERPTS FROM BOSTON CITY ORDINANCE OF 1961 PREVIOUSLY CONTROLLING NOISE (NOW SUPERSEDED)

<u>Chapter 29</u>: Establishes and defines prohibitions and penalties.

<u>Section 97</u>: Defines and prohibits "Unnecessary Noises" (Note: This section is removed entirely by later Ordinance).

A. "...unreasonably loud, disturbing and unnecessary noise...prohibited. Noise of such character as to be detrimental to life or health...prohibited."

B. "...following acts declared...in violation...but... not deemed exclusive...."

Horns 1. "...sound of horn...on vehicle...not in motion, except as a danger signal;...[or] while in motion...[when] deceleration is intended...."

Music 2. "...playing of any radio, phonograph or any musical instrument...in such a manner or with such volume to annoy or disturb...persons in any dwelling...provided such noise...plainly audible at...50 ft...[excepts band and orchestras]."

Animals 3. "...keeping...animal or bird...which by... causing frequent or long continued noise shall disturb...any person...."

Vehicles 4. "...use of any...vehicle so out of repair or so loaded...to create loud and unnecessary grating grinding rattling or other noise... plainly audible at...100 ft."

TABLE 15 *(Continued)*

Whistles	5.	"...blowing of any steam whistle...except to give...time...or as an alarm...."
Mufflers	6.	"...discharge of exhaust of steam or... internal combustion engine except through a muffler...which will effectively prevent loud or explosive noises...."
Construction	7.	"...erection, demolition, alteration or repair of any building...except between... 7 a.m. or 6 p.m. on weekdays...except... on issuance of permit...."
Street Activity	8.	"...creation of excessive noise on any street adjacent to any school,...court, hospital, or church which unreasonably interferes...[and is] plainly audible at...25 ft...."
Loading	9.	"...excessive noise...loading or unloading... or opening and destruction of...containers."

TABLE 16

COMMENTS ON THE APPLICABILITY OF THE CITY OF BOSTON ZONING CODE TO NOISE CONTROL

Article 2 — Definitions

p.5 Section 2-1 Between #33 and #34: Definition of "noisy", "noise" is lacking.

Article 6 — Conditional Uses

p. 13 Section 6-3: "The Board of Appeal shall grant...appeal [for conditional use of land] only if...no *nuisance* will be created by the use..." ("nuisance" not defined, but could include noise)

p. 13 Section 6-4: "Other Conditions Necessary as Protection... Board...may attach...safeguards...to assure harmony...with intent of this code." (noise could be mentioned here)

Article 7 — Variances

p. 17 Section 7-4: "Other conditions...Board of Appeal may attach...Conditions...[such as]...limitation of...method and time of operation...." (suggest a noise standard would be helpful for zone)

Article 8 — Regulation of Uses

p. 22 Use #19: "...Machine shop or noisy activity accessory to a school...provided that...in the opinion of the Board...[it] is adequately sound-insulated to protect the neighborhood from

TABLE 16 *(Continued)*

	unnecessary noise...." (needs standards and clarification)
p. 23 Use #24:	"...Scientific...laboratories...provided that... no noise or vibration is perceptible without instruments more than 50 ft from the lot...." (needs clarification)
p. 24 Use #28:	"...private grounds for games and sports... provided that...[there is no] indoor or out-door activity which is in itself noisy. (needs standards and clarification)
p. 25 Use #29:	"...Adult education center, community center [etc.]...[as above in Use #24]...." (needs standards and clarification)
p. 26 Use #37:	"...Lunch room, restaurant [etc.]...provided that there is no dancing and entertainment other than phonograph radio, and television...." (noise restrictions may need to be applied)
p. 27 Use #38:	"...Place for sale and consumption of food... providing dancing or entertainment...concert hall; dance hall; skating rink; bowling alley;... sports center...." (noise restrictions may need to be applied)
p. 28 Use #49:	"...Animal hospital...kennel; pound...." (noise restrictions may already apply)
p. 29 Use #52:	"Drive-in theatre; stadium...." (noise restrictions might be considered)

TABLE 16 *(Continued)*

p. 31 Use #60:	"...Repair garage...provided that...shop... is sufficiently sound-insulated to confine all noise to the lot...." (needs clarification and standards)
p. 33 Use #66:	"...Helicopter landing facility...." (noise standards might be referenced here)
p. 33 Use #67:	"...Airport...." (same as above)
p. 33 Use #68:	"...Any industrial use...which does not result in noise or vibration perceptible without instruments more than 50 ft outside, the perimeter of the lot...." (needs clarification)
p. 36 Use #70:	"...Any [industrial] use which is objectionable or offensive because of...noise or vibration perceptible without instruments more than 250 ft outside the perimeter of the lot or if a residential district is within 250 ft of the lot...." (needs standards)
p. 39 Use #72A:	"...a swimming pool or tennis court lot within a...front yard...." (noise restrictions may be needed here)
p. 41 Use #77:	"...keeping laboratory animals...provided that all resulting noise [is]...effectively confined to the lot...." (needs clarification and standards)
p. 42 Use #81:	"...the manufacture, assembly or packaging of products sold on the lot...." (noise standard should perhaps be applied here)

TABLE 16 *(Continued)*

p. 50 (and following) Article 14: Lot size, Area & Width

There is an opportunity to insert generalized noise standards as a function of type of zone (see Table B opposite p. 50 as a logical insertion point)

V. PROPOSED INITIAL NOISE REGULATIONS

There follows a set of regulations proposed for initial adoption by the City of Boston Air Pollution Commission to initiate a noise control effort in the City. The regulations are cited here in nonlegalistic language, both to promote ready understanding of their meaning and to permit freedom in final drafting by the Commission itself to meet the Commission's own legal style.

At the suggestion of the Commission, the regulations proposed are to be self-standing, complete within themselves, to become a document separate from existing air pollution regulations.

A. Overall Regulatory Powers of the Air Pollution Control Commission re Noise (Preamble)

Based on the enabling Ordinances of the City of Boston[1] and General Laws of the Commonwealth,[2] the City of Boston Air Pollution Control Commission will undertake noise control. Four general areas for control are proposed herein: a) restricting noise according to the Zoning Districts of the City (Regulation 4); b) restricting noise from construction site operations (Regulation 5); c) limiting noise from vehicles for sale or lease (Regulation 6); and d) restricting noise from powered devices for sale or lease (Regulation 7).

The range of penalties and the powers of enforcement are [or should be] set by City Ordinance[3] and State Law,[4] and hence are

[1]Ordinance of March 16, 1970.

[2]G.L. 40:21(22) (1969)
G.L. 111:31C (1963) – needs further clarification to include noise.

[3]Ch. 29 – needs clarification *re* penalties.

[4]Ch. 111:31C – needs clarification *re* enforcement.

implicit in the Commission's Regulations. Noise regulations for certain noise sources are preempted by or will be covered by coordinate enforcement agencies (e.g., vehicle horn blowing may possibly come under the jurisdiction of the Police Department in the future; snowmobile noise control is already under regulation by Division of Motorboats of the State Registry of Motor Vehicles).

B. Definitions of Key Terms (Regulation 1)

The acoustical terms used throughout the regulations are those as defined by the U.S. standards-setting body or ANSI (The American National Standards Institute). The regulatory body involved is currently pinpointed as the City of Boston Air Pollution Control Commission.

For purposes of identifying those responsible for noise intrusions across zone boundaries or lot lines, the responsible unit will be the "single legal entity". This "entity" is defined as the corporation, firm or individual who controls noise emissions through owning, leasing or operating one or more facilities within a single zone. The noise emission over which this "entity" shall be responsible shall be defined as the summed (or total) noise levels resulting from all operations of that "entity" that normally emit noise simultaneously.

C. Procedures for Noise Measurement (Regulation 2)

The Commission is responsible for establishing procedures for the measurement of: 1) noise from specified operations (such as at construction sites as in Procedure No. 1), 2) noise from certain articles for sale or lease (primarily vehicles as in Procedure No. 2 and powered equipment as in Procedure No. 3), and 3) noise at the boundaries of zoning districts and certain lot lines within those districts (as in Procedure No. 4).

Proposed noise measurement procedures covering the above types of measurement situations are recited separately (in Appendix C). These procedures follow accepted measurement practices and are drawn verbatim from the various referenced standards of the U.S. and international standards-setting bodies.

All measurements, except for Zoning District measurements, are to be made in a single-number measurement system — i.e., in A-Weighted sound level units, or dB(A). This single number system encompasses the whole acoustic spectrum heard by the human ear, and is weighted to match the hearing characteristics of the ear. In the case of the Zoning District measurements, levels are to be measured in each of nine frequency bands (octave bands); impulsive and intermittent noises are specifically singled out for measurement using appropriate procedures.

The single-number system is chosen, where applicable, not only because of ease of measurement but because it is truly representative of the quantitative value of noise nuisance anticipated from sources such as vehicles and powered equipment for which the acoustic spectrum and intrusion duration are generally predictable. The additional complexity of octave-band and impulsive or intermittent measurements is justified in the case of Zoning Districts because the noises expected cover an unpredictable range of acoustic spectra and durations.

D. General Prohibition of Noise Emissions (Regulation 3)

Owners, lessors, and those who control certain emissions of noise as described herein, are generally prohibited from causing noise nuisances as delimited in these noise regulations.

E. Noise Restrictions According to Zoning Districts (Regulation 4)

1. Definitions and Interrelationships with Boston City Zoning Code (Regulation 4.1)

For purposes of restricting noise by land use, the City is assumed to be divided into general land use categories as established by the Zoning Code, namely: 1) Residential; 2) Business; 3) Restricted Manufacturing plus Waterfront Industrial; and 4) General Industrial. Accordingly, maximum acceptable noise levels, measured in octave-bands, are established for either the property lot lines within such Districts or the zone boundary lines shared between such Districts (whichever is deemed necessary to limit noise intrusions by abutters or from adjacent zones). The definitions of the Zoning Districts and the permissible land uses therein are those already established by the Boston Zoning Code.

2. Restrictions on Noise Emitted Within Residential Zoning Districts (Regulation 4.2)

Within all forms of Residential Zoning Districts (encompassing "S" or single family districts, "R" or general residential districts, and "H" or apartment districts), the noise emitted by any single residential unit shall not exceed the following levels, when measured at the emitter's lot lines:

Octave Band Center Frequency of Measurement (Hz)	Maximum Sound Pressure Levels at Lot Line of the Emitter (dB)
31.5	72
63	71
125	65
250	57
500	51
1000	45
2000	39
4000	34
8000	32
Approx. Single-Number-System Equivalent (for Preliminary Survey and Monitoring Only)	55 dB(A)

3. Restrictions on Noise Emitted from Within Business Zoning Districts (Regulation 4.3)

Within all Business Zoning Districts (encompassing "L" or Local Business Districts and "B" or General Business Districts), the total noise emitted by any single legal entity shall not exceed the following levels, when measured at the lot lines or zone boundaries indicated:

Octave Band Center Frequency of Measurement (Hz)	Maximum Sound Pressure Levels Measured At: Emitter's Lot Lines Shared With Any Abutting Business Properties In The Business Zone	Maximum Sound Pressure Levels Measured At: Emitter's Zone Boundary Lines Shared With Any Adjacent Residential Zone
31.5	79 dB	72 dB
63	78	71
125	72	65
250	64	57
500	58	51
1000	52	45
2000	46	39
4000	41	34
8000	39	32
Approx. Single-Number-System Equivalent (for Preliminary Survey and Monitoring Only)	62 dB(A)	55 dB(A)

4. Restrictions on Noise Emitted From Within Restricted Manufacturing and Waterfront Industrial Zoning Districts (Regulation 4.4)

Within Restricted Manufacturing as well as Waterfront Industrial Zoning Districts (encompassing all "M" and "W" Districts), the total noise emitted by any "single legal entity" shall not exceed the following levels, measured along the abutting zone boundary lines indicated:

Octave Band Center Frequency of Measurement (Hz)	Maximum Sound Pressure Levels Measured At Emitter's Zone Boundary Lines Shared With	
	Abutting Business Zones	Abutting Residential Zones
31.5	79 dB	72 dB
63	78	71
125	72	65
250	64	57
500	58	51
1000	52	45
2000	46	39
4000	41	34
8000	39	32
Approx. Single-Number-System Equivalent (for Preliminary Survey and Monitoring Only)	62 dB(A)	55 dB(A)

5. Restrictions on Noise Emitting From Within General Industrial Zoning Districts (Regulation 4.5)

Within General Industrial Zoning Districts (encompassing all "I" Districts), the total noise emitted by any "single legal entity" shall not cross any boundaries of Residential or Business Zoning Districts at levels exceeding the following levels measured along the zone boundary lines indicated:

Octave-Band Center Frequency of Measurement (Hz)	Maximum Sound Pressure Levels Measured At: Emitter's Zone Boundary Lines Shared With Abutting Business Zones	Emitter's Zone Boundary Lines Shared With Abutting Residential Zones	Boundary Lines of Nearby Residential Zones Not Directly Abutting Emitter's Zone
31.5	80 dB	75 dB	72 dB
63	79	74	71
125	74	69	65
250	69	64	57
500	63	58	51
1000	57	52	45
2000	52	47	39
4000	48	43	34
8000	45	40	32
Approx. Single-Number-System Equivalent (for Preliminary Survey and Monitoring Only)	66 dB(A)	61 dB(A)	55 dB(A)

F. Restrictions on Noise Emitting from Construction Sites (Regulation 5)

1. Construction Site Operations with Nominal Background Noise (Regulation 5.1)

No construction site shall be operated in a manner to emit noise in excess of the following levels, measured in accordance with the procedures prescribed by the Commission for determining "Construction Site Operation Sound Levels".*

Zoning District in which Construction Site Located	Construction Site Operation Sound Levels	
	7:00 p.m. to 8:00 a.m.	8:00 a.m. to 7:00 p.m.
Residential ("S", "R", or "H")	45 dB(A)	75 dB(A)
Business ("L" or "B")	45 dB(A)	80 dB(A)
Restricted Manufacturing and Waterfront Industrial ("M" or "W")	45 dB(A)	80 dB(A)
General Industrial ("I")	75 dB(A)	85 dB(A)

*In brief, the measurement points will be at any area open to the public except public ways, or at a 1000-ft radius from the site, whichever is nearer the construction site.

2. Restrictions on Noise from Operating a Construction Site Which Adds to Existing High Background Levels (Regulation 5.2)

In the event that the background sound level ("Baseline Level") measured at a construction site while construction is not in progress is found to be already in excess of the maximum levels delineated in the foregoing section, subsequent construction operations shall not be permitted that will raise the total sound levels by 2 dB(A) or more, measured as in the preceding section. Methods for establishing the levels of background noise are established by the Commission as procedures for measuring "Construction Site Baseline Levels".

G. Restrictions on Noise Emitted from New Vehicles For Sale or Lease (Regulation 6)

1. Definitions (Regulation 6.1)

a. *Motor Vehicle* shall be defined as in the General Laws of the Commonwealth, Chapter 90, Section 1, titled "Definitions".

b. *Motorcycle* shall also be defined in accordance with the same reference above.

c. *Light Motor Vehicles* shall be defined as all motor vehicles having a gross vehicle weight of 6,000 lb and less.

d. *Heavy Motor Vehicles* will be defined as all motor vehicles having a gross vehicle weight in excess of 6,000 lb.

e. *Recreational Vehicle* shall be defined in accordance with the Massachusetts Division of Motor Boats Recreational Vehicle Law, Chapter 589, Acts of 1970, as:

> "...a motor vehicle designed to travel over unimproved terrain and which has been determined by the registry of motor vehicles as unsuitable for operation on the public way and not eligible for registration under chapter ninety."

2. New Vehicle Noise Restrictions

No person shall sell or lease a new motor vehicle that produces a maximum noise exceeding the following limits (measured at a distance of 50 ft from the centerline of travel, in accordance with the procedures established by the Commission):

	Light Motor Vehicle (6,000 G.V.W. or Less)	Heavy Motor Vehicle (Over 6,000 lb. G.V.W.)	Motorcycle
After 1 Jan. 1968	--	88 dB(A)	--
After 1 Jan. 1970	--	--	88 dB(A)
Before 1 Jan. 1973	86 dB(A)	--	--
After 1 Jan. 1973	84 dB(A)	86 dB(A)	86 dB(A)
After 1 Jan. 1975	80 dB(A)	84 dB(A)	84 dB(A)
After 1 Jan. 1980	75 dB(A)	75 dB(A)	75 dB(A)

Recreational vehicle noise restriction shall be as stated in the Massachusetts Division of Motor Boats Recreational Vehicle Law as cited above.

H. Restrictions on Noise Emitted from New Outdoor Powered Equipment For Sale or Lease (Regulation 7)

1. Definitions (Regulation 7.1)

a. *Light Homeowner's Residential Outdoor Machinery* shall be defined as all engine- or motor-powered garden or maintenance tools intended for repetitive use in residential areas, typically capable of being used by homeowner (such as lawn mowers, garden tools, riding tractors, snow blowers, snow plows, etc.).

b. *Commercial Service Machinery* shall be defined as all engine- or motor-powered equipment intended for infrequent service work in inhabited areas, typically requiring commercial or skilled operators (such as chain saws, pavement breakers, log chippers, etc.).

c. *Commercial Agricultural Machinery* shall be defined as all engine- or motor-powered equipment typically associated with agricultural operations (such as tractors).

d. *Construction and Outdoor Industrial Equipment* shall be defined as all engine- or motor-driven outdoor equipment, whether mobile or stationary, which is associated with construction sites or industrial operations. Specifically *excluded* are pile drivers.

2. Noise Restrictions (Regulation 7.2)

No person shall sell or lease any new outdoor powered equipment that produces a noise level exceeding the following limits (measured at a distance of 50 ft, under test procedures established by the Commission):

	Light Home'rs. Resd'l. Outdoor Mach'y.	Comm'l. Service Mach'y.	Comm'l. Agr'l. Mach'y.	Constr. and Outdoor Ind'l. Equip.
Manufactured after				
1 Jan. 1972	74 dB(A)	88 dB(A)	88 dB(A)	94 dB(A)
1 Jan. 1973	--	84 dB(A)	--	88 dB(A)
1 Jan. 1975	70 dB(A)	--	86 dB(A)	--
1 Jan. 1978	65 dB(A)	--	--	--
1 Jan. 1980	--	80 dB(A)	80 dB(A)	80 dB(A)

I. Standardized Qualifying Regulations

In keeping with practices already established in existing regulations of the Commission, there will be need for a series of qualifications at the end of the noise control regulation set which cover conflict, variances and severability.

We foresee that these qualifying regulations can follow the patterns already set by the B.A.P.C.C. Accordingly, we propose to base the new qualifications on "Regulations for the Control of Atmospheric

Pollution" adopted by the Commission on December 22, 1969. We summarize the results here below:

1. Conflict with Other Regulations (New Regulation Designator X)

The noise regulations shall not relieve any person from complying with other laws, statutes, codes, regulations or ordinances of the Commonwealth or the City of Boston.

2. Variances (New Regulation Designator Y)

The Commission may grant variances after public hearing and approval by the Department of Public Health of the Commonwealth, or may reject applications on review without a hearing. Variances thus granted may be effective for no longer than one year. In granting a variance, the Commission shall not allow the creation of any condition of noise intrusion.*

3. Severability (New Regulation Designator Z)

If any part of the above regulations is judged to be legally invalid, the remainder of the regulation(s) shall continue in force.

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*The philosophy voiced in this sentence, although general in nature and apparently self-contradictory, has permitted the Commission to operate in the past in matters of air pollution variances. It is used again here based on its record of being both effective and practical.

VI. RELEVANT NOISE CONTROL TECHNOLOGY

A. Commercially Available "Quieted" Equipment

This section presents information on "quieted" versions of equipment whose unquieted versions are contributors to Boston's noise environment.

1. Portable Air Compressors

Portable air compressors act as primary driving units for many individual pieces of machinery. These units have three main sections, all of which must take in and exhaust air: the engine, the engine cooling system or radiator, and the compressor. In a "quieted" unit, the problem becomes one of building an enclosure having many holes in it and, at the same time, having good noise reduction qualities. Ingersoll-Rand Corporation has demonstrated a solution to this problem with reductions of about 15 dB(A). Figure 12 shows the noise reduction achieved on a 900-cfm portable air compressor [*14*]. The principal noise control modifications include a damped sheetmetal housing that incorporates exhaust and intake mufflers, and glass fiber compressor fan blades. The cost difference between the unsilenced and silenced units of these 900-cfm models represents an increase of 25%, and the cost difference for the 175-cfm units represents an increase of 8%. Worthington Corporation is expected to release a line of silenced units in the spring of 1971. In each case, these quieted units are marketed in addition to, rather than in place of, the cheaper unquieted standard units.

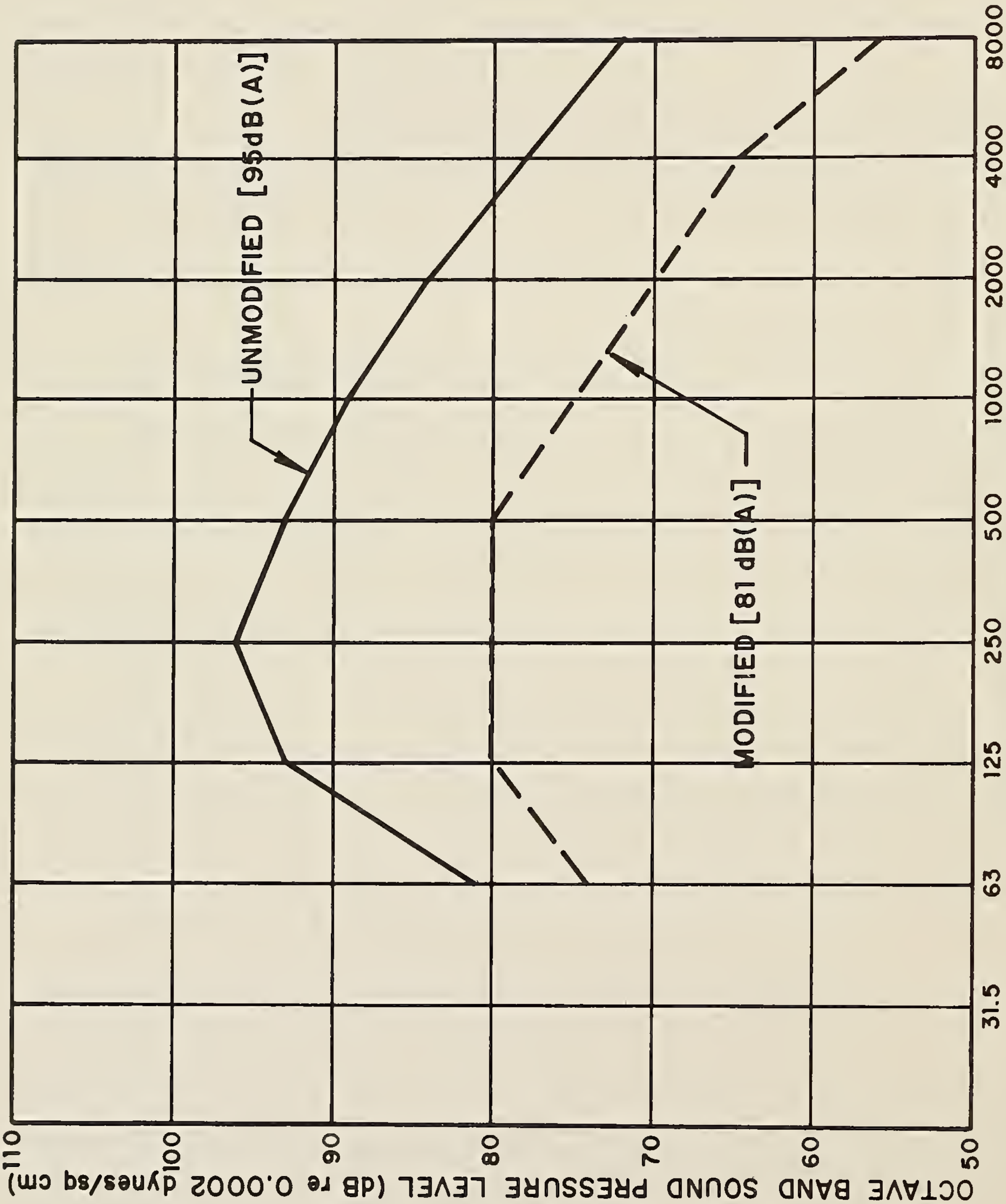


FIG. 12 PORTABLE AIR COMPRESSOR NOISE LEVELS (Averages of Measurements at 7m From 900-cfm Compressors; From Ref. 14)

2. Pavement Breakers

Pavement breakers are a major source of construction noise. Several firms in the United States and Europe are developing quieted breakers or silencers for conventional breakers. Figure 13 shows noise levels measured 10 ft from a conventional pneumatic breaker and a silenced hydraulic breaker. The hydraulic breaker is reported to require 18% more time to break the same thickness and area of concrete as the pneumatic breaker. Even so, it is preferable to have the longer duration with the noise levels reduced by 11 dB(A). The British Building Research Station reports noise reductions of 6 to 8 dB(A) by modifying pneumatic breakers, and reductions up to 20 dB(A) by using these modified breakers in partial enclosures.

3. Pile Drivers

The pile driver is another common source of construction noise. As with most pieces of equipment, there are two major source components — the driving unit and the working member. The driving unit can be a gasoline, diesel, or steam engine. Contributions from the intake and exhaust are predominant in the driving unit noise. Although the technology for designing intake and exhaust silencers is available, it is not often applied in the manufacture of present-day construction equipment. Typical noise reductions of 10 to 15 dB(A) can be achieved with such silencers. Further reductions generally require enclosing the equipment to muffle the noise of moving mechanical parts.

The working member can be a drop hammer, an air ram, or a vibrating element. The latter two types are inherently quieter than the drop-hammer pile driver, with its high impact noise levels.

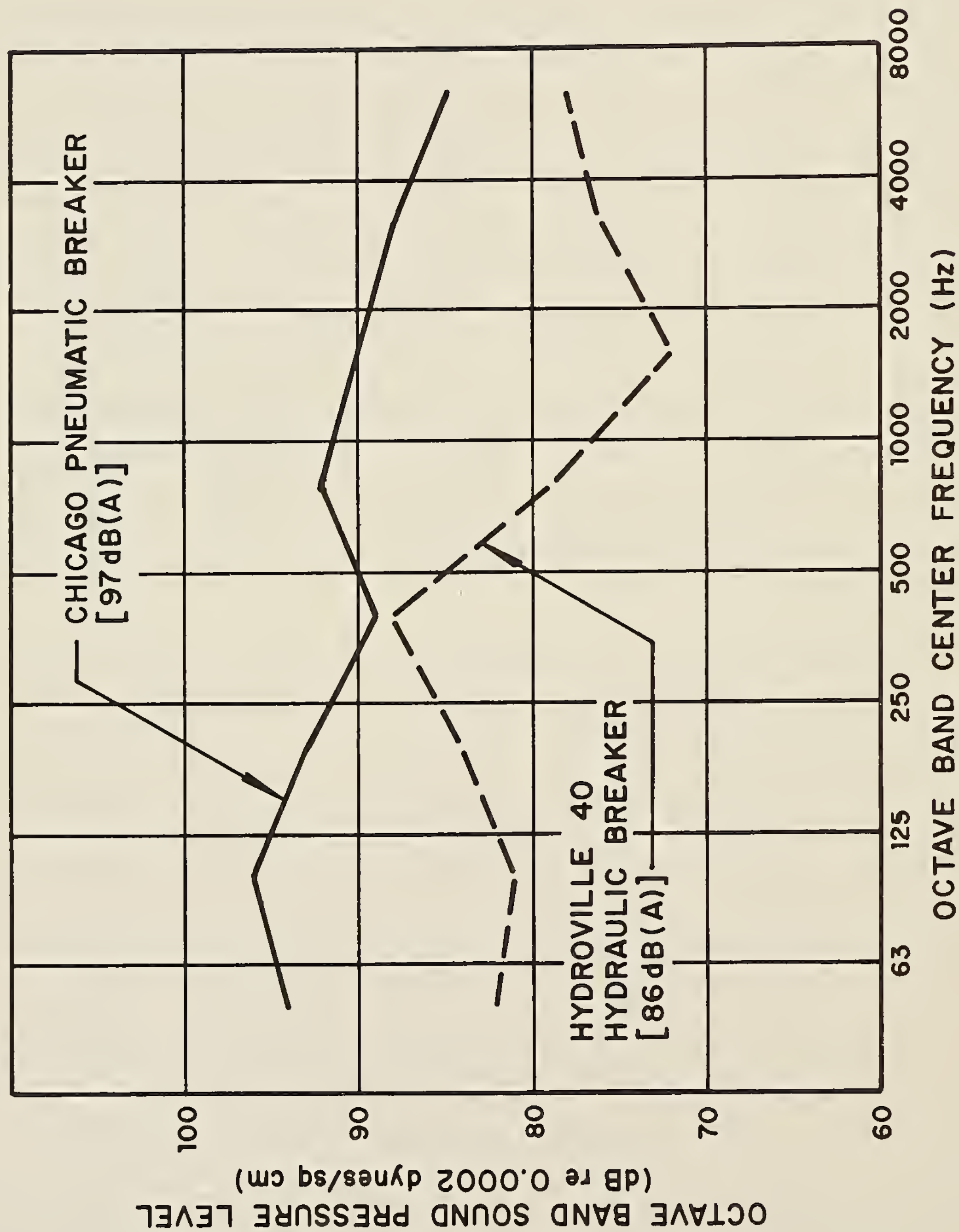


FIG. 13 CONCRETE BREAKER NOISE LEVELS (Measurements at 10 ft From Concrete Breaker)

The noise of a resonant vibrating-element pile driver is estimated to be approximately 20 dB less than the impact noise of a drop-hammer pile driver. (The resonant vibrating-element pile driver can also drive piles as much as five times faster than the other types, in some soil conditions.) It is therefore acoustically preferable to avoid the use of the drop-hammer pile driver. Unfortunately this is the type of pile driver in most widespread use in Boston, because of its suitability for many local soil conditions and because of prevalent engineering procedures. Some advantage might be achieved by using two types of pile drivers, for example, using a resonant vibrating-element driver to drive piles to a certain depth, and then finishing the drive with a drop-hammer driver.

4. Refuse Trucks

A vehicle source that has received some engineering attention is the refuse truck. Noise from refuse trucks is associated with two sources: the engine and the compactor hydraulic equipment. Most of the hydraulic system noise come from the pump. General Motors has accomplished noise reductions of 8 to 10 dB(A) by using a better engine exhaust muffler and replacing the conventional gear pump with a screw pump.

B. Three Case Studies

The following material discusses three noise sources found in the City of Boston: a factory, a railroad yard, and rapid transit vehicles. Each of these sources has recently been the cause for unsolicited complaint in nearby residential areas. This material describes the extent of each problem and presents some general suggestions on how noise control might be implemented.

1. Factory Noise

The factory building selected for this study lies in an M-1 ("Restricted Manufacturing") zone. It is approximately 100 by 200 ft in plan, and two stories high. Major continuous noise sources are boilers and roof-mounted air handling and paper-board scrap collection equipment. The collector consists of a cyclone on the roof with a large duct running up from inside the building. The noise that is most apparent at the factory property line is a combination of boiler room noise, cyclone fan motor noise, and air turbulence noise punctuated by a rattling sound. The rattling appears to be emitted by the collection system. The collection system noise exists approximately 16 hours a day, 5-1/2 days a week. Other parts of the plant operate 24 hours a day, 5 days a week. The plant is adjacent to an S-5 ("single family") zone as well as near an R-5 and L-5 zone. For the S-5 residential area considered, the noise levels associated with actual fabrication processes in the building do not appear to be major contributions to the community noise levels, although they could become more important during the warmer weather when factory doors and windows may be open.

Trucks that load and unload at several of the docks around the factory generate intermittent noise levels that may exceed the noise levels of the roof-mounted equipment. The truck operations occur usually during the day. Adjacent to the factory loading docks one hears the typical truck noise of accelerating from stop and idling. The noise varies depending upon the size of the truck and its mode of operation.

The distance from the residential area considered to the factory building is approximately 200 ft, with direct line-of-sight to the roof air handling equipment and one of the truck loading docks. There are 8 to 10 homes situated in this way. Figure 14 presents the range of octave band sound pressure levels measured

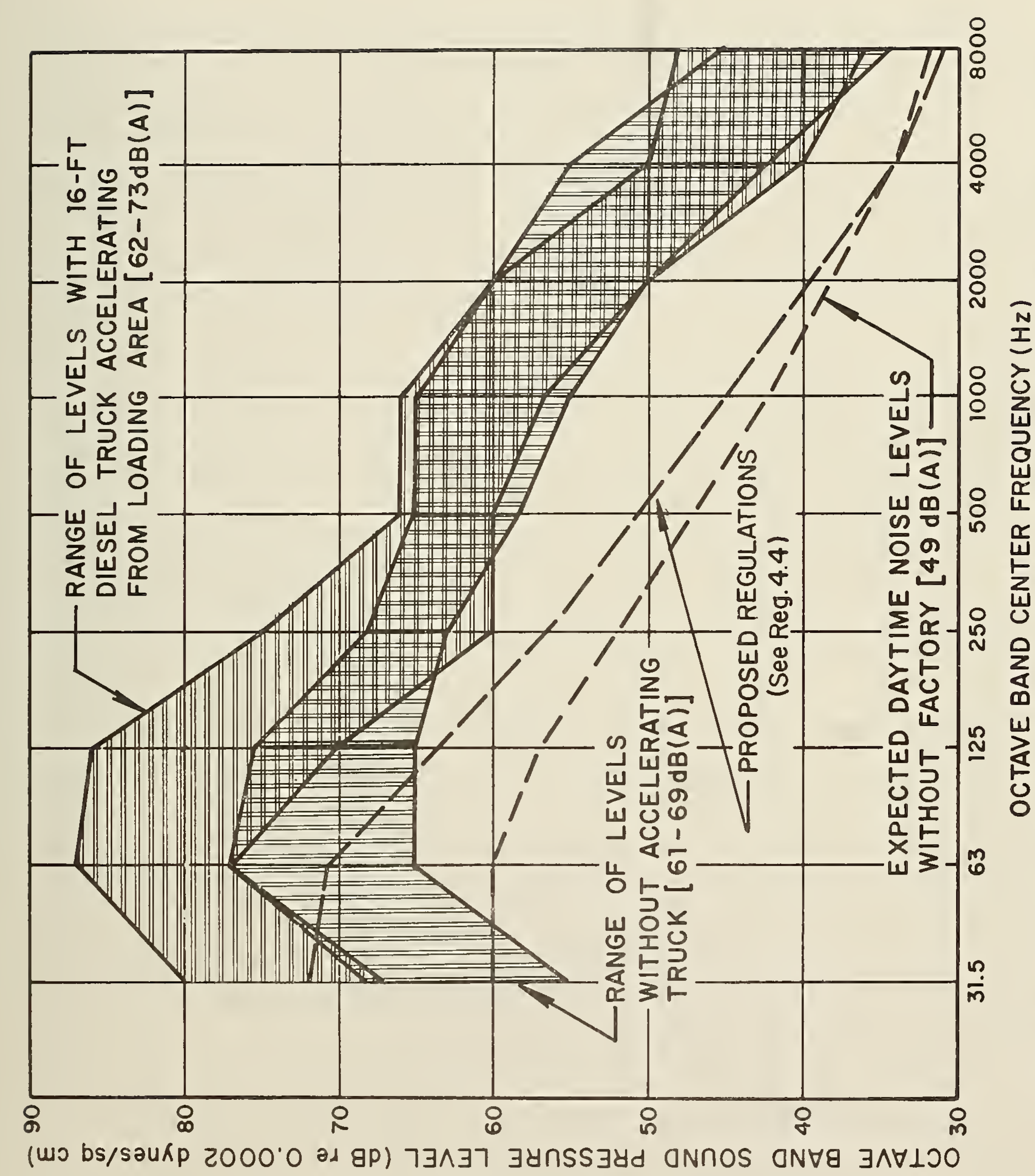


FIG. 14 BOX FACTORY NOISE LEVELS MEASURED AT RESIDENCE 200 FT FROM FACTORY

at one of the residences approximately 200 ft from the factory noise sources, and the range of levels measured at the same position during the slow acceleration of a diesel truck at the loading area. The broken line in Fig. 14 is an estimate of the daytime noise that might be expected in the residential area in the absence of the factory. These noise levels would be associated primarily with the traffic on the roadway several hundred feet from the residential area. (Nighttime noise levels would be estimated to be about 15 dB lower.) The figure suggests that the factory noise levels exceed the expected daytime levels by 12 to 20 dB, and that the truck noise levels are as much as 10 dB higher at the lower frequencies. Note the comparison of observations with the prosed regulation-based levels. The noise of the factory and trucks clearly constitutes a problem, and this conclusion is borne out by complaints from neighboring residents.

Several noise control procedures could be explored to reduce the factory noise in the surrounding community. The fan noise could be reduced by improved fan mountings and the erection of partial barriers or complete enclosures around the fans. A noise reduction of 15 to 20 dB should be achievable in this way. Without a detailed inspection of the collection system, it is not possible to suggest any control procedures, but damping and lagging of the collector duct might be appropriate for reducing the rattling noise. If it is assumed that the trucks are properly muffled, reduction of truck noise might require enclosures around the loading area, to remove the trucks from line-of-sight of the neighbors.

2. Railroad Yard Noise

Noise due to the operations in railroad yards is a significant problem in several residential neighborhoods of Boston. In portions of these yards railcar sections are switched from side tracks

to the main line or to other tracks by diesel switchers. These switchers are often idling for long periods of time. When the switcher is about to move a section of cars, there is a pneumatic noise and also a rattling noise as the train couples and the brakes are released. In addition to the noise of the diesel switcher, there is the noise of other passing trains and their whistles. There is also the noise of the refrigeration units on stationary boxcars that may operate continuously through the night.

At one railroad yard in Boston, there is a S-5 ("single family") zoned residential street adjacent to the yard (M-1 or "Restricted Manufacturing" zone) and about 5 ft below the yard. Switching operations are located in clear line-of-sight to the residences. The average distance from the houses to the nearest side track is about 100 to 125 ft. Most of the houses have two or three stories. There are about 30 homes which front on this particular street.

Figure 15 shows the range of noise levels of the idling diesel switcher engine, measured at the neighborhood 100 ft away compared to the maximum levels suggested by the proposed regulations. The highest levels in the range are those measured during the passage of a freight train 250 ft from the neighborhood. Noise levels produced by the boxcar refrigeration units were below the range of levels shown on Fig. 15. The broken line in Fig. 15 is an estimate of the daytime noise levels that might be expected in the absence of the railroad yards. The train noises are seen to exceed the expected daytime levels by 15 to 30 dB, clearly constituting a neighborhood noise problem.

Several approaches could be explored to reduce the railroad yard noise in this community. One effective approach would be to

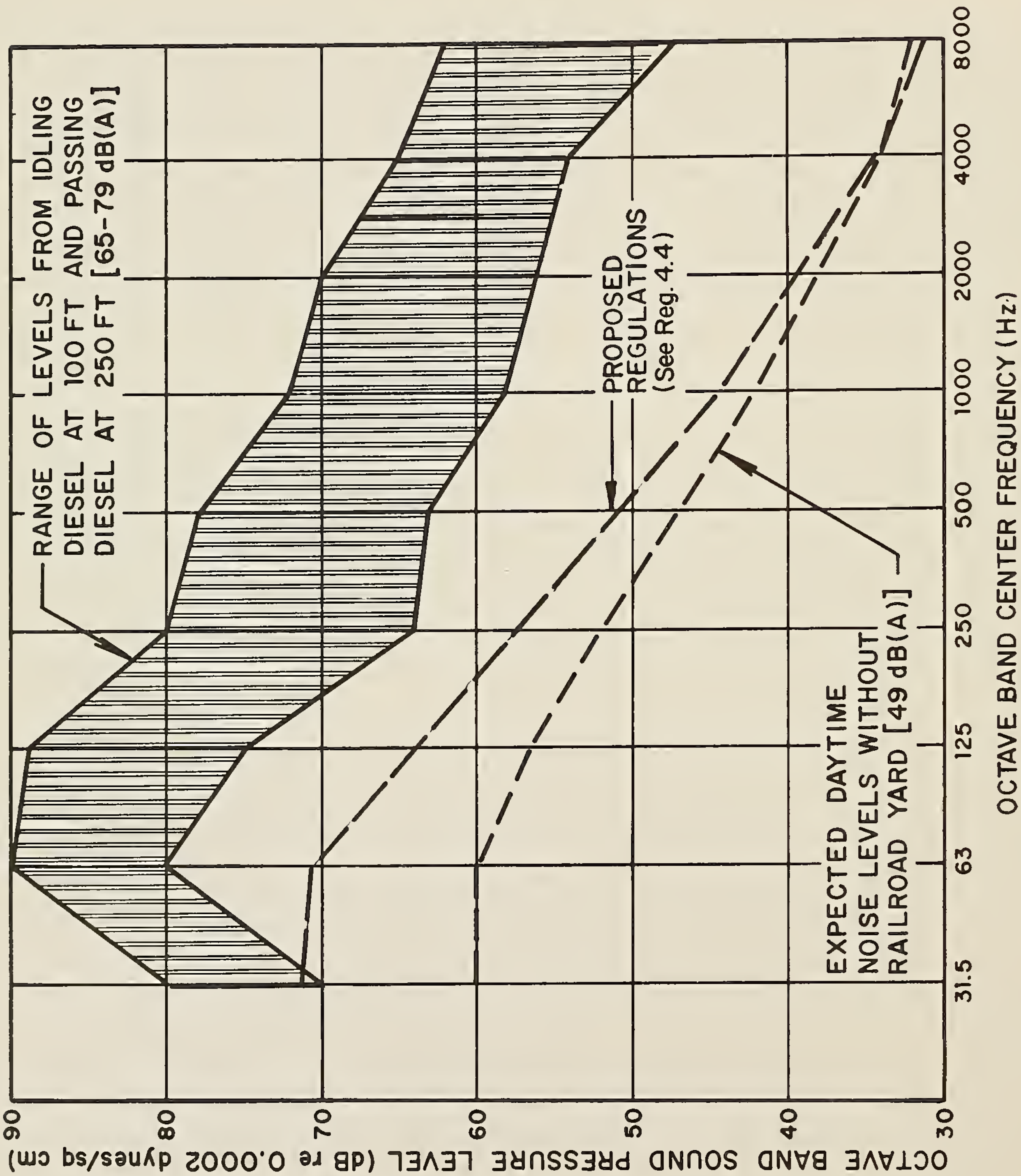


FIG. 15 RAILROAD YARD NOISE MEASURED AT NEARBY RESIDENCE

move the switching operation of the railroad cars. It appears that the operations could be carried out as much as several thousand feet from the residential area. Such a move could reduce the noise levels by as much as 20 dB. Another approach might be to schedule the operations so that there would be no yard work done during the hours of 11:00 p.m. to 6:00 a.m. in the portion of the yard near residential neighbors, although this schedule may be impractical. Trains passing through the yard might be routed to avoid areas near residential neighborhoods. Engineering noise control measures could also be considered for the diesel switchers and the boxcar refrigeration units. Experience indicates that 10 dB or more reduction might be achieved by proper muffling of the engine exhausts and intakes.

3. Rail Transport Systems

A major noise problem associated with rail transport systems is wheel squeal, the high-frequency sound generated by rail vehicles rounding sharp bends. This sound may be very disturbing to passengers within the vehicles and on station platforms, as well as to occupants of buildings near above-ground traffic sections. Squeal is associated with a stick-slip phenomenon occurring between the vehicle wheel and the rail. It appears that most of the energy is radiated from the wheels, although relatively little is known quantitatively about the squeal mechanism. Frequency analysis of squeal noises show strong tonal components occurring typically at frequencies around 3000 Hz, although some squeal samples show significant frequencies as low as 800 Hz. These tonal components may extend as much as 20 dB above the levels produced by nonsqueal conditions.

Wheel-squeal noise may be eliminated by several different physical modifications at or near the wheel. One approach is lubrication of the rails. Such lubricators have been installed at a short section of the outer curved MBTA track near North Station. These lubricators spray a mixture of water and oil on each rail. Recent spot measurements indicate that lubrication provides an average reduction of approximately 10 dB(A), corresponding to a greater reduction at the actual squeal frequency [*15*]. Lubrication may involve some difficulties, such as spraying of nearby people or reducing necessary friction between wheel and rail.

Another squeal control approach is the application of damping to car wheels to attenuate the resonant vibration [*16*]. The problems encountered with damping materials, such as loss of bond strength during heating or mechanical loading, interference with fixtures used to hold wheels during grinding, and cost, do not appear insurmountable.

A third approach is to attach a strip of material to the head of one of the rails. The material must be sufficiently strong to support the loads, be durable, and have a low coefficient of friction when in contact with steel wheels. We understand that the use of such a material in a European subway has been reported effective, and we are attempting to determine more information on this treatment. A final control approach is the use of wheels with the rim separated from the hub by a resilient material [*17*].

The wheel-rail interaction is also responsible for much of the other (nonsqueal) noise associated with rail transport systems. Existing information suggests that the presence of rail joints produces increases of approximately 8 dB at all frequencies over

the levels that would be observed with welded rails [*18*]. Wheel and rail roughness and rail corrugations also give rise to increased wheel-rail noise. There is some indication of high-frequency noise associated with flange lateral impact or rubbing. Reduction of these various sources would thus require an improved knowledge of the detailed mechanisms involved and the closer control of rails and wheel dimensions.

Brake squeal may be generated by excitation of various brake components. Control treatment usually involves structural modification, the use of different brake-shoe material, and/or the damping of certain structural members. Noise from equipment, including traction motors and auxiliary equipment, may involve airborne transmission (as in the case of fan exhausts) or structureborne transmission (as in the case of vibrating panels). Control of airborne noise may require mufflers or baffles; control of structureborne sound may require damping or vibration isolation.

The measures discussed so far involve reduction of noise at or near the vehicle source. In many cases, these measures may not be appropriate or adequate. Further reduction can then be accomplished by acoustical treatment of the transmission path, by the introduction of barriers or (in the case of enclosed spaces such as underground stations) the introduction of acoustic treatment. Certain features are essential in barriers: they must involve rigid walls combined with sound-absorbing material facing the noise-producing wheels, they should be continuous with no openings, and they should be erected along the entire length of curved sections of tracks. Such barriers can provide between 5 and 20 dB of noise reduction, depending on the details of

geometry and the particular frequency range under consideration. Selective application of acoustical materials in stations can provide reductions of approximately 6 to 10 dB [*15*].

A comparison of the magnitude of the observed levels with those proposed under the new regulations may be seen in Fig. 16. The cross-hatched range of data in this figure show noise levels measured within a B-4 ("General Business") zone inside a hotel room 50 ft from an MBTA track near North Station. The exterior construction of the room involved a wall of normal construction with closed double hung sash windows. The broken line in Fig. 16 shows a criterion commonly used for living and sleeping spaces. A comparison between that criterion and the range of measured data indicates that the rail vehicle noise exceeds the criterion by 10 to 25 dB. Wheel-squeal noise was plainly audible in the 4000-Hz octave band, and a more detailed set of analyses than shown in Fig. 16 would make this squeal noise component apparent.

The geometry of the elevated track and high surrounding buildings indicates that it would be impractical to consider a barrier here. It would be difficult to build a barrier which would be extensive enough to block the noise paths to the high building.

C. Cost-Effectiveness and Cost-Benefits

Most of the noise control discussed above involves increased costs for present operators. An analysis of the cost effectiveness is beyond the scope of this report, but becomes increasingly important as regulatory pressures are brought to bear on the operator. Cost-benefits won by noise reduction will now become a matter of judgment by the regulatory bodies involved as community pressures are brought to bear.

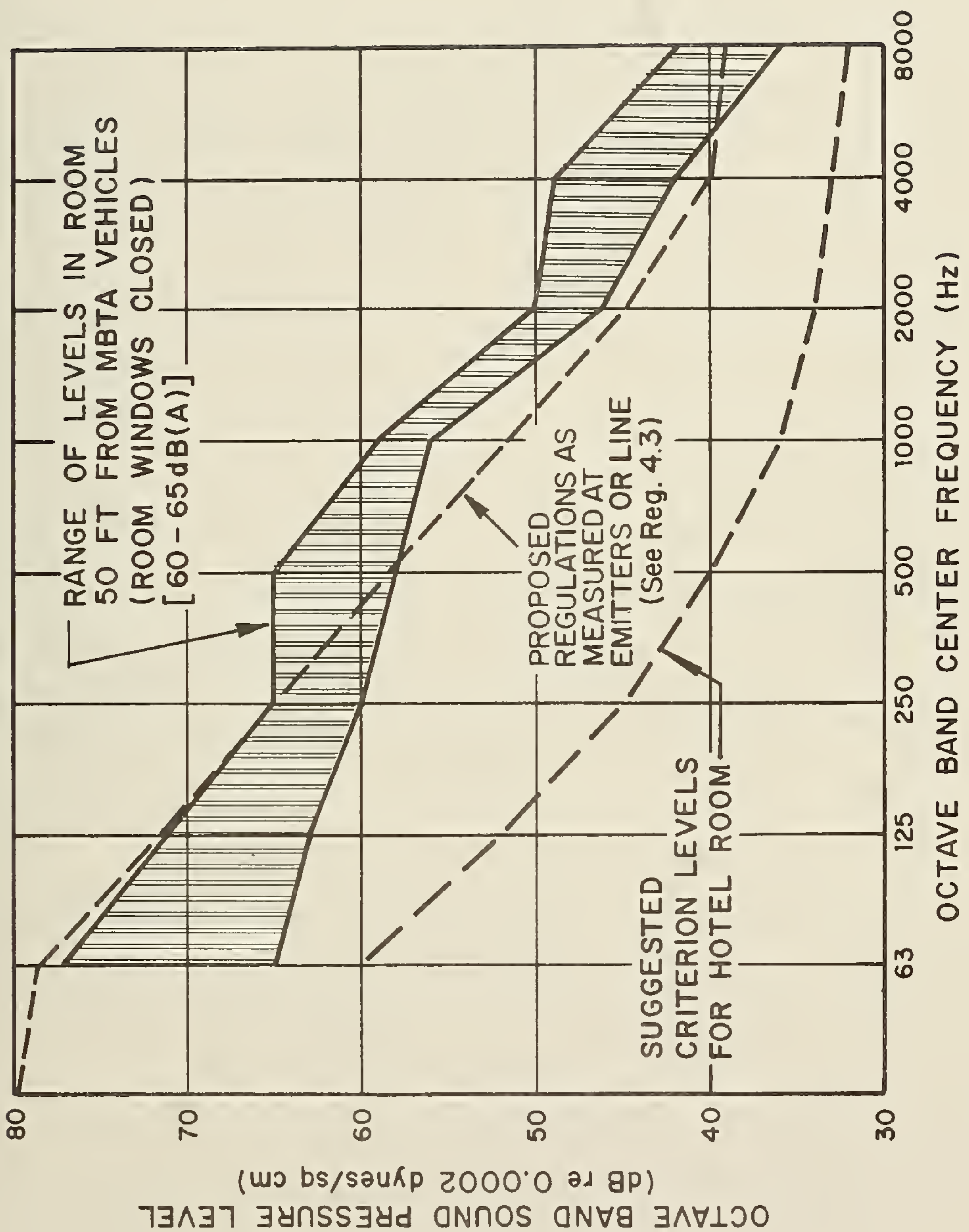


FIG. 16 RAIL TRANSPORT NOISE MEASURED IN HOTEL ROOM

VII. RECOMMENDED FOLLOW-ON PROGRAMS

Follow-on effort should now take two forms: 1) an immediate series of steps should be taken to implement the regulations presently proposed; and 2) a longer-range program should be started to expand noise control in the future so that the City of Boston moves toward achieving the community standards proposed herein.

There follows a listing (not necessarily in order of priority) and brief definition of the near-term steps and long-term programs recommended for noise control by the Boston Air Pollution Control Commission.

A. Immediate Next Steps

1. Review Findings and Proposed Regulations

There undoubtedly is a need to present and explain the results of this analysis and plan, especially to those regulatory bodies who are concerned with noise control as well as to groups who may be affected by the regulations.

To expedite the review process, sixteen wall charts have been prepared which summarize the findings and proposals of this report. This should provide the Boston Air Pollution Control Commission with the necessary "tools" to transmit the results of this effort in a complete yet summary form.

2. Back-up Ordinances and General Laws

The important matters of enforcement responsibility, power and procedures, as well as nature of penalties need still to be clearly established. To back up the propose regulations, ordinances are needed specifically directed toward clarifying the jurisdiction of

the Boston Air Pollution Control Commission over matters of noise control. To backstop still further the powers of the City Council to pass on adequate jurisdiction to the B.A.P.C.C., it may be necessary to seek more definitive General Laws regarding such elements as injunctive relief.

The background presented in this study should serve to guide the drafting of supportive City Ordinances and General Laws of the Commonwealth. The exact form such Ordinances and Laws should take is beyond the scope of this present report.

3. Agreements With Coordinate Enforcement Bodies

Other City bodies will inevitably be involved in enforcement of noise controls; similarly, certain State bodies will be concerned with complementary noise control efforts. The B.A.P.C.C. will want to work jointly with coordinate enforcement groups during initiation of back-up Ordinances and General Laws as well as during the finalization of the specific City noise regulations and measurement procedures.

4. Compatibility With Zoning Code

The regulations proposed have been designed to be compatible with the intent of the Current Zoning Codes of the City of Boston. In fact, zone definitions are used which are currently in force in detail. However, some of the generalized noise control language currently contained in the use restrictions within the Code should be reviewed with an eye toward substituting the more specific controls proposed in the new noise control regulations.

5. Finalization of Initial Regulations and Procedures

The regulations offered here are precisely stated as to permissible noise levels, but are cited in plain language form for the convenience of the reader. An obvious next step is to re-phrase as necessary to meet the legal requirements of a formalized Ordinance. The drafting in legal form is left to the B.A.P.C.C. to assure that the language used will be compatible with the City's own legal needs.

The measurement procedures, on the other hand, are in a form that can be issued without re-work. A final review should be made of the procedures to assure that the techniques are brought fully up to date in this fast-changing field.

B. Longer Range, Future Programs

1. Horn-Blowing Restrictions

Regulations restricting the blowing of vehicle horns are deferred until such time as the City feels that it can actually enforce such measures. Although an obvious source of noise nuisance, prevention of horn blowing requires an extensive, quick-response type of enforcement, followed by a streamlined legal procedure. Restrictions on horn blowing will hopefully be considered at a time in the future when practical enforcement and legal follow-up is possible.

2. Restrictions on Running Engines of Vehicles While Stationary

We foresee an early consideration of additional regulations to restrict noise nuisance from vehicle engines being run while the vehicle is not underway. (Obvious examples being waiting buses and cooling units on refrigerated vans.)

3. Public Education Program

An encouraging amount of public awareness is currently being generated by local and national news media. The stage is thus set for the City's regulatory bodies to launch a public education program backing noise control. The emergence of a set of regulations, and the formalization of the activities of the Boston Air Pollution Control Commission in the field of noise control can serve as aids in nucleating public attention.

4. Restrictions on Vehicles in Use

It may be necessary to await State action on restricting noise from vehicles in use. Starting with City-wide restrictions on new vehicles for sale or lease will, we hope, help focus on this, the most serious of City noise problems.

5. Noise Control Via Building Codes

The introduction of increasingly tight indoor noise control via the City of Boston Building Code should eventually be considered. Once experience is gained with the restrictions initially proposed based on the Zoning Code, it may be possible to extend noise control into the potentially important area of building codes.

6. Airport Noise Abatement

Via the proposed restrictions on noise based on land use (i.e., Zoning Codes), the City has a start on some phases of airport noise control. Noise from ground operations such as run-up or engine testing can be controlled. Flight operations still remain outside City control. There is, however, a new body of law emerging regarding total airport noise impact.

During the remainder of 1971, the attempts on the part of the State of California to limit airport noise impact will probably be tested, and the potential roles of aircraft operator, airport management, local and state government, and the Federal Aviation Administration will probably be increasingly clarified for the rest of the nation. Accordingly, the future opportunities of the Boston Air Pollution Control Commission to participate in airport noise abatement should become increasingly clear throughout the last half of 1971.

7. Occupational Health and Safety

Federal laws have set precedence for hearing protection in industry; in the future, the City may want to extend protection into areas not now covered. Whereas the established Walsh-Healey Act and the new Occupational Health and Safety Act apply to specific government contracts and certain interstate commerce, the City will want to consider whether local protection will be necessary through introduction of City-wide occupational health and safety regulation.

APPENDIX A

Selection of a Single-Number Noise Measure

In general, a noise signal may be thought of as a composite of sounds extending from the low-frequency roars to the high-frequency hisses. People not only distinguish the high-frequency components from the low-frequency components in a composite noise, but they also find high-frequency noises much more annoying than low-frequency noises of the same sound level. Therefore, to evaluate in detail how disturbing each noise will be, we should know how much of the total sound energy is contained in each of the bands of frequency.

If we were to perform this task of frequency analysis on a routine basis, it would require keeping track of the entire set of frequency-band sound levels for each noise, usually 8 or 9 octave bands, or as many as 25 one-third-octave bands, in the frequency range extending from 31 to 8,000 Hz. Furthermore, these noise levels will usually fluctuate in time, and we must therefore account for the time-varying level in every band. This is obviously a considerable chore.

Much effort has been devoted to the development of rating scales that simplify the task described in the previous paragraph. In a period of just 40 years, several dozen schemes have been developed to rate noise in terms of some aspect of predicted human response[*19*]. Superficially, these many schemes appear to vary widely, both in degree of complexity and actual detail of composition. During the past years, however, the general opinion has been

developing that for most noises of common interest, all the most useful ratings provide much the same predictions with much the same degrees of precision.

In principle, the simplest rating scale is one that gives equal weighting to all frequency components in the audible range. The resulting number is called the "overall sound pressure level." Unfortunately, this simple measure is one of the least useful of the many proposed ratings, because (as mentioned earlier) the human hearing mechanism is not uniformly sensitive to all frequency components, but gives increased emphasis to higher frequency components.

Fortunately, there is a relatively simple weighting network that approximates the response of the average human ear to sounds of different frequencies. This network utilizes an electrical circuit that is built into every precision sound level meter. A measurement with a sound level meter incorporating such a network yields a single number called the A-weighted Sound Level (or A-Level) expressed in decibels and abbreviated "dB(A)". The added letter, "A", signifies that the sound level so expressed represents the *weighted* sum of all the components of the noise. Table A-I shows the value of A-levels for typical noises in outdoor and indoor environments, along with the corresponding judgments of relative loudness of these noises.

Many recent studies have shown that the description of common sounds in terms of A-Levels correlates very well with more complicated ratings developed for evaluating (or predicting) subjective responses to noise.

TABLE A-I Sound Level and Loudness of Typical Noises in Indoor and Outdoor Environments [21]

A-WEIGHTED SOUND LEVEL IN dB(A)	SUBJECTIVE IMPRESSION	COMMUNITY* (Outdoor)	HOME OR INDUSTRY* (Indoor)	RELATIVE LOUDNESS (Human Judgment of Different Sound Levels)
130		Military Jet Aircraft Take-off With After-Burner From Aircraft Carrier @ 50 ft (130)	Oxygen Torch (121)	32 Times as Loud
120	Uncomfortably Loud	Turbo-Fan Aircraft @ Take-off Power @ 200 ft (118)	Riveting Machine (110) Rock-N-Roll Band (108-114)	16 Times as Loud
110		Jet Flyover @ 1000 ft (103) Boeing 707, DC-8 @ 6080 ft Before Landing (106) Bell J-2A Helicopter @ 100 ft (100)		8 Times as Loud
100	Very Loud	Power Mower (96) Boeing 737, DC-9 @ 6080 ft Before Landing (97), Motorcycle @ 25 ft (90)	Newspaper Press (97)	4 Times as Loud
90		Car Wash @ 20 ft (89) Prop. Plane Flyover @ 1000 ft (88), Diesel Truck, 40 mph @ 50 ft (84), Diesel Train, 45 mph @ 100 ft (83)	Food Blender (88) Milling Machine (85) Garbage Disposal (80)	2 Times as Loud
80				

*Numbers in parentheses are representative A-Levels

TABLE A-I (Continued)

A-WEIGHTED SOUND LEVEL IN dB(A)	SUBJECTIVE IMPRESSION	COMMUNITY* (Outdoor)	HOME OR INDUSTRY* (Indoor)	RELATIVE LOUDNESS (Human Judgment of Different Sound Levels)
80	Moderately Loud	High Urban Ambient Sound (80), Passenger Car, 65 mph @ 25 ft (77), Freeway @ 50 ft from Pavement Edge, 10 AM (76±6)	Living Room Music (76) TV-Audio, Vacuum Cleaner (70)	REFERENCE LOUDNESS 70 dB(A)
70		Air Conditioning Unit @ 100 ft (60)	Cash Register @ 10 ft (65-70), Electric Type-writer @ 10 ft (64) Dishwasher (Rinse) @ 10 ft (60) Conversation (60)	1/2 as Loud
60	Quiet	Large Transformers @ 100 ft (50)		1/4 as Loud
50		Bird Calls (44) Lower Limit Urban Ambient Sound (40)		1/8 as Loud
40	Just Audible	[dB(A) Scale Interrupted]		
10	Threshold of Hearing			
0				

Table A-II presents the results of a study of 66 samples of industrial and transportation noise. The table shows the difference in value between the Speech Interference Level (a rating designed specifically to relate to the intelligibility of speech communication) and four other ratings that were not specifically designed to relate to speech intelligibility [22]. The four other measures are Overall Sound Pressure Level, A-Level, Perceived Noise Level (a rating developed specifically to rate the "noisiness" of aircraft noise), and a noise rating measure proposed by a draft of the International Standardization Organization. The mean values of the differences between these four measures and the Speech Interference Level range from 4 to 21. Of greater interest than these mean values, however, are the range of differences, which are an indication of the dissimilarities between the ratings being compared. Inspection of the range of differences indicates that three of the four scales agree well with the Speech Interference Level scale, even though these three scales were not designed specifically to measure speech interference. Only overall sound pressure level, that contains no frequency weighting, shows a poor agreement with Speech Interference Level.

Table A-III summarizes the information on ten of the most important scales proposed for relating noise to some aspect of subjective response. A detailed discussion of these scales and other matters related to the assessment of community noise problems is given in Ref. 23.

The many studies analyzed and summarized in Ref. 23 show consistently the utility of the A-Level in predicting various aspects of subjective response, including noisiness, speech intelligibility, loudness, acceptability, etc.,

TABLE A-II Means and Standard Deviations of Difference Distributions Between Speech Interference Level and Four Other Possible Measures of Speech Interference[22].

	Mean Difference	Standard Deviation of Difference
Overall Sound Pressure Level (L_C)	14	5.6
A-Weighted Sound Level (L_A)	8	2.3
Perceived Noise Level	21	3.3
ISO Noise Rating	4	2.4

TABLE A-III Rating Scales of Major Interest [23]

Name	Construction	Use	Comments
Overall Sound Pressure Level	Uniform emphasis given to all frequency components over the audible frequency range	Sometimes used to characterize sounds in general	Essentially the same as C-weighted sound level
A-weighted Sound Level	Reduced emphasis given to frequency components below approximately 1000 Hz	Correlates well with relative loudness and "noisiness" of many common sounds	Relates approximately to sensitivity of ear at moderate levels
Loudness Level	Complex combination of frequency components according to one of two procedures (Zwicker or Stevens)	Relates to results of laboratory loudness studies	Attempts to account for masking by prominent frequency components, of sound stimulus at other frequencies
Articulation Index	Addition of signal-to-noise levels, in bands, weighted by relative contribution of each to speech intelligibility	Predicts speech intelligibility with good accuracy	Subject to errors of prediction for non-contiguous narrow bands of noise
Speech Interference Level	Arithmetic average of sound-pressure-levels in 3 (or 4) octave bands covering frequency range of primary importance for speech	Relates to speech intelligibility	Used widely in evaluating aircraft cabin noise
Perceived Noise Level	Complex combination of frequency components greatest importance to the most prominent frequency band	Relates to results of laboratory "noisiness" studies; used in certification tests of new types of aircraft	Uses same addition rule as Stevens' loudness level calculation
Noise and Number Index — 1963 (NNI)	Perceived noise level and number of events	Aircraft takeoffs and landings	Relates to interview responses in residential areas
Traffic Noise Index (TNI)	A-weighted sound level and temporal statistics of noise over 24-hour period	Urban automotive traffic	Relates to interview responses in residential areas
Noise Pollution Level — 1969 (Robinson)	A-weighted sound level or perceived noise level and temporal statistics of noise over specified period (usually day or night)	Community noise in general, with mixed noise sources	Must be combined with contextual factors to be used as a predictive procedure
ISO Noise Rating (N or NR) Curves and Noise Criterion (NC) Curves	Octave band spectrum, rated as to how far it protrudes into a family of "level rank" curves	Used to rate indoor noise exposure, particularly office, auditorium and residential community noise	

for most common sounds encountered in the urban environment. In all but the most particular kinds of research, the A-Level correlates practically as well with human response as any of the other established ratings. It has the further merit of simplicity, to such an extent that it will lend itself well to monitoring urban noise levels. Finally, the A-Level has already been widely chosen in other measurement programs so that the results from measurements in Boston can be readily compared with those of other workers. Therefore, we recommend the use of the A-Level as the base measure for much of the Boston Noise Abatement Program. We revert to the more comprehensive octave-band system only where needed — in land use (zoning) measurements.

It should be pointed out that there will be a definite, although limited, need in the Boston Noise Abatement Program for complete frequency analyses of noises. Such situations will occur when there is a need to determine the relative importance of sources producing the noise or to evaluate the effects of various possible modifications of a noise-producing device. In other words, when the selection of a specific noise abatement measure is of interest, a complete frequency analysis will usually be required.

APPENDIX B

Frequency Analyses of Boston Construction Site Noise

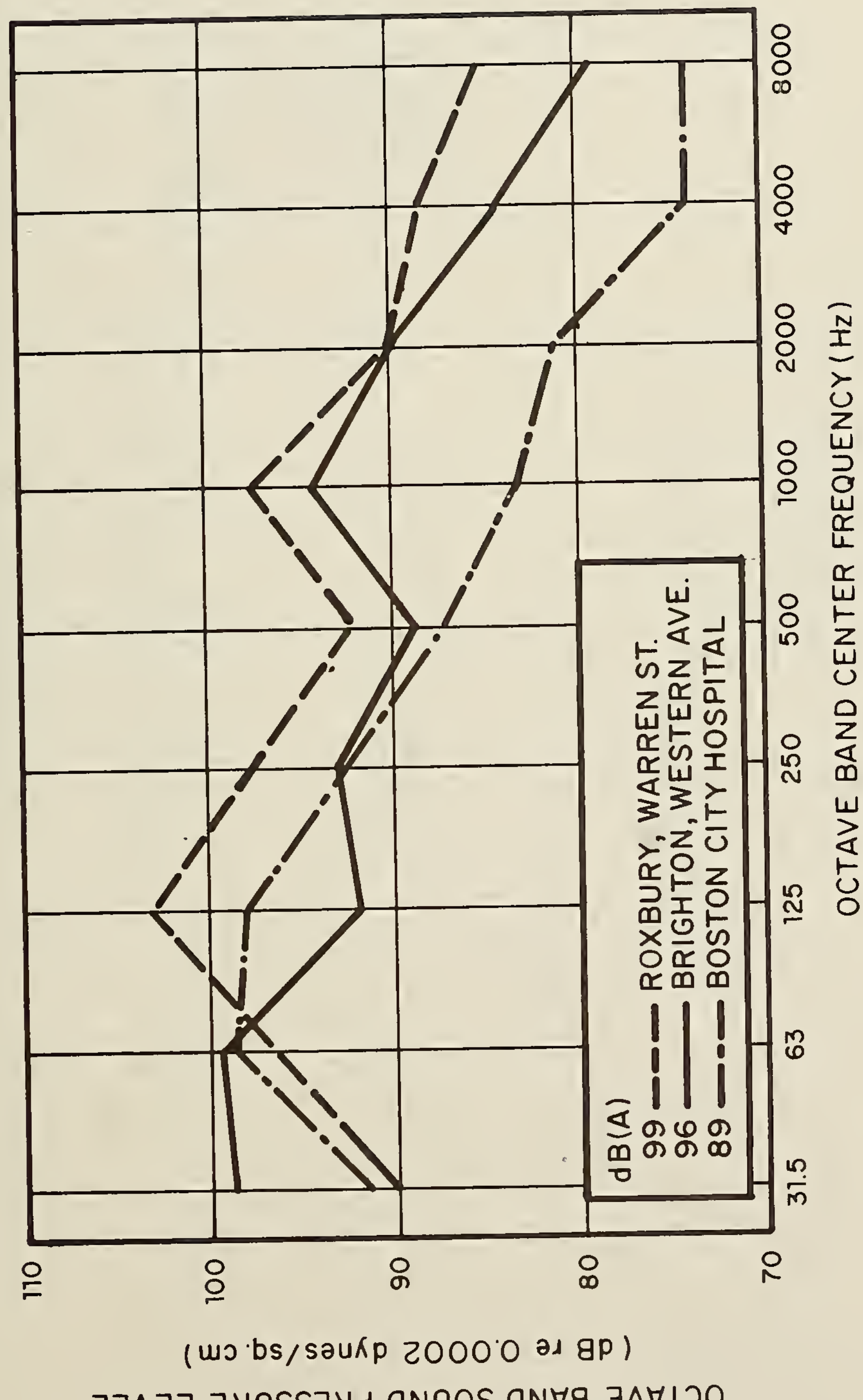


FIG. B-1. BACKHOE NOISE LEVELS (Data Normalized To 50 Ft)

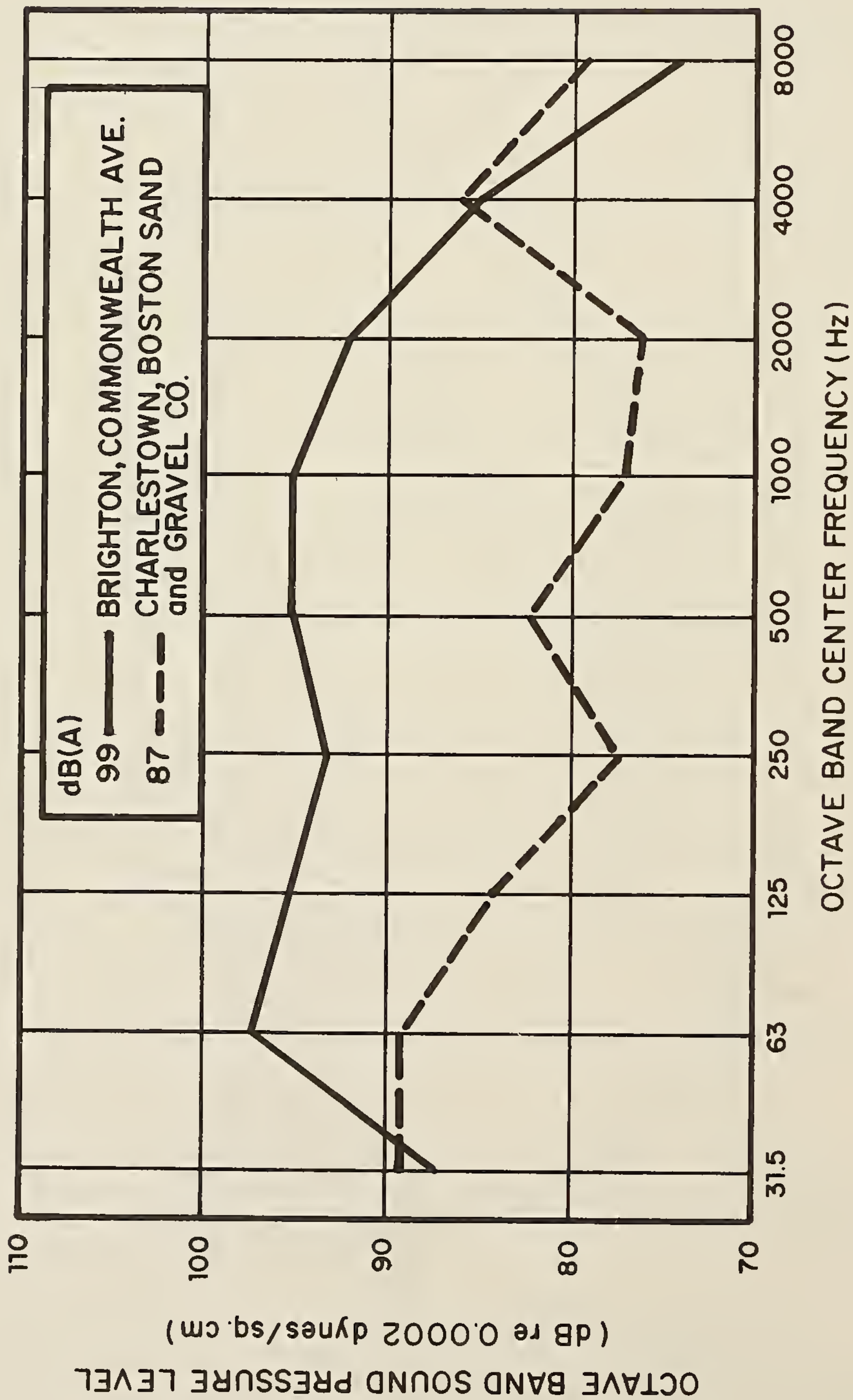


FIG. B-2 CRANE NOISE LEVELS (Data Normalized to 50 Ft).

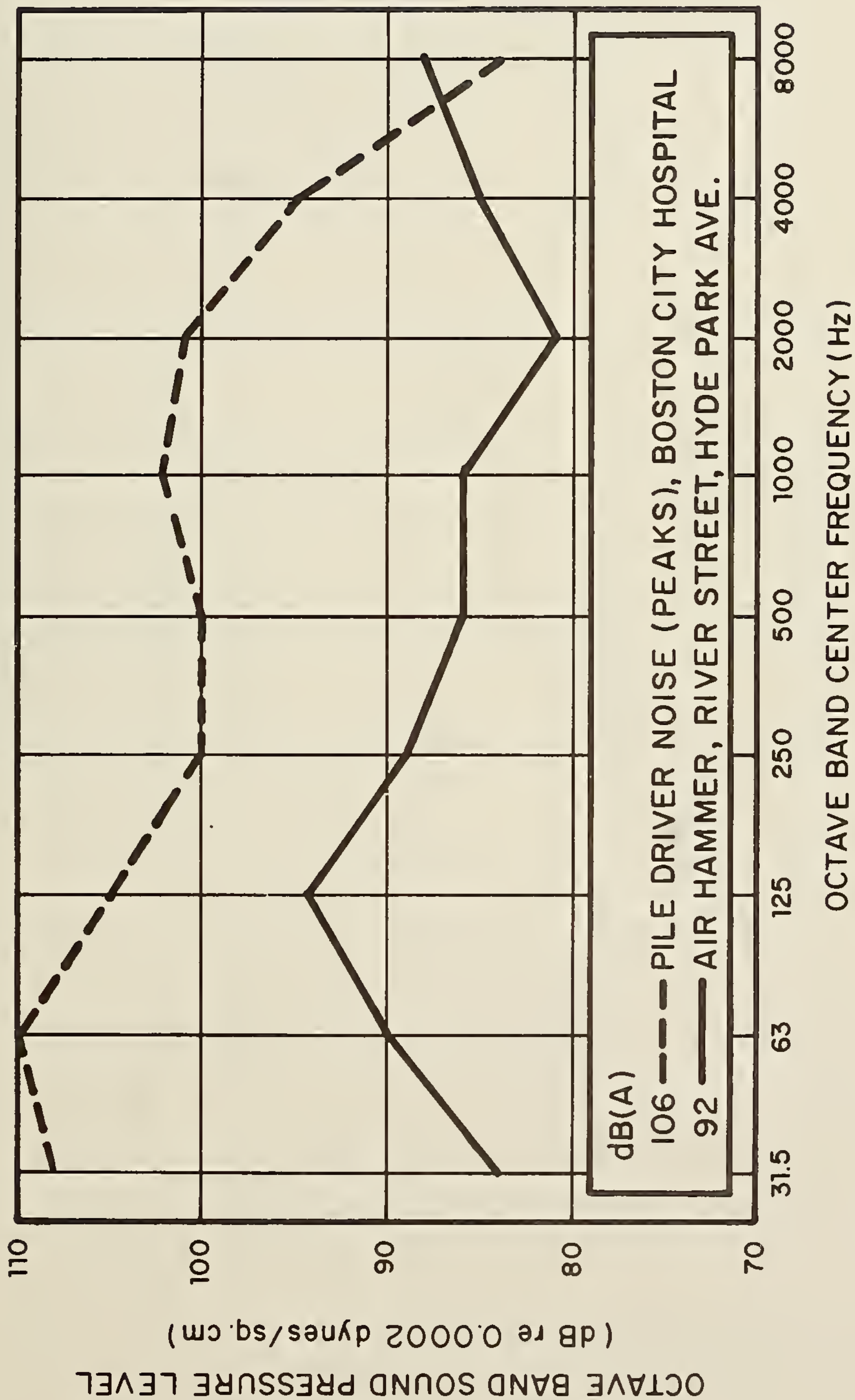


FIG. B-3. AIR HAMMER AND PILE DRIVER NOISE LEVELS (Data Normalized to 50 Ft)

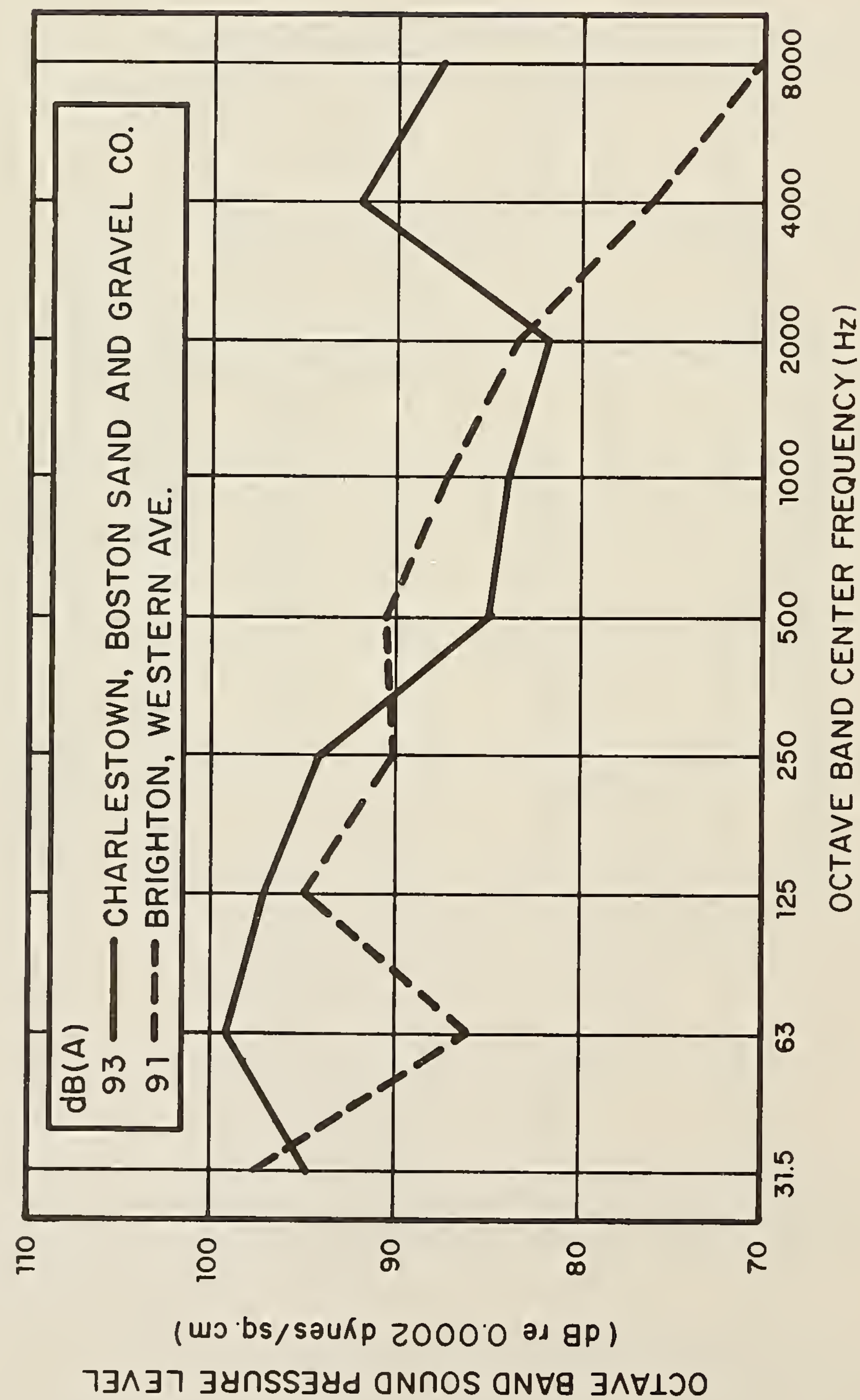


FIG. B-4. TRUCK NOISE LEVELS (Data Normalized to 50 Ft)

APPENDIX C

Procedures for Measuring Noise

INTRODUCTION

The noise control regulations proposed for the City of Boston reference certain test procedures to be established by the Commission. This Appendix presents the proposed procedural regulations recommended for adoption by the Commission to accompany the various sections of the regulations.

These procedures are in substantial conformance with standards and recommended practices established by engineering societies and voluntary standards organizations, recognized nationally and internationally. These procedures do not specify any limits or performance; this is done solely within the regulations themselves. These procedural regulations merely provide clear-cut guidelines for the measurements necessary to test compliance with the proposed regulations.

1. CONSTRUCTION SITE NOISE MEASUREMENT

1.1 Purpose. The following test procedures are to be used to determine that the maximum noise emitted from a construction site shall meet the noise limits stated in the Noise Control Regulations. These procedures define the noise measurement locations and the noise measurement technique.

1.2 Personnel Qualifications. Persons selected to conduct the noise measurement testing described below shall have been trained and qualified in the techniques of sound measurement and the operation of sound measuring instruments.

1.3 Instruments Required. Instrumentation used in making the noise measurements shall be selected by technically trained personnel and shall meet SAE Recommended Practice J184 *Qualifying a Sound Data Acquisition System.*

1.4 Site Determination. Obtain sufficient drawings, survey stake locations and pertinent information to determine site boundaries.

Obtain information in sufficient detail to determine location and flow pattern of construction machinery.

Identify significant noise sources.

Lay out centerpoints of activities (major noise sources) for the construction site machinery.

Determine the four nearest areas open to the public, except public ways, within 1000 ft from significant noise sources and the centerpoints of activities. If there are no inhabited locations within

1000 ft of any significant noise source and/or centerpoint, select four locations at approximately 90° from each other at 1000 ft from each significant noise source or centerpoint of activity.

<u>1.5 Baseline (Background) Noise Measurement.</u> At the selected locations, position the noise-measuring microphone at least 4 ft above the ground, and 3 ft (± 1/2 ft) in front of any window, door, or wall affected. These noise measurements shall be taken of the ambient noise condition (wind velocity under 12 mph) when there is no construction machinery in operation at the site, at a time when the traffic and other activities in the area are at their noisiest. These readings will be called "Construction Site Baseline Sound Levels". If it is intended to operate the construction site at night then the procedure shall be repeated at night.

<u>1.6 Construction Site Operation Sound Level Measurement.</u> Repeat the procedure described in the paragraph above with construction machinery operating in a normal work cycle for this construction site. These readings will be called "Construction Site Operational Sound Levels".

<u>1.7 Equipment Setup and Use.</u> The microphone shall be oriented relative to the source of the sound in accordance with the instrument manufacturer's instructions to provide a uniform frequency response.

Bystanders occupying positions in the vicinity of the microphone will influence the test results. Instrument manufacturer's specifications for the location of the observer relative to the motor shall be adhered to.

When using a windscreen it should be calibrated for the type of noise source being measured and data corrected if necessary.

Sound level measurements shall be taken using the A-Weighting network with the meter set for "fast" meter response.

The number of meter readings at each microphone position will depend upon the fluctuation of the noise level. Observations shall be repeated until the number of readings equals or exceeds the range in decibels of the A-Weighted sound levels obtained. Readings more than 10 dB(A) below the maximum reading shall not be considered valid. The average of all valid readings shall be reported as the noise level for that particular test condition.

Manufacturer's recommended calibration practice of the instruments shall be followed. External (end-to-end) calibration checks shall be made before and after each period of use and at intervals not exceeding one hour when the instrument is in use longer than this time.

1.8 Noise Level Tolerance. Allowances are necessary due to unavoidable variations in measuring sites, test equipment, temperature and wind gradients. "Construction Site Operational Sound Levels" shall not be considered in violation unless they exceed the dB(A) levels in the regulations by more than 1 dB(A).

2. NEW MOTOR VEHICLE NOISE MEASUREMENT

2.1 Purpose. The following test procedure shall be used to determine that the maximum noise emitted by new motor vehicles offered for sale or lease shall meet the noise limits stated in the regulations. This procedure includes noise testing of: (1) Motorcycles, (2) large motor vehicle (gross vehicle weight of 6000 lb or more), (3) small motor vehicles (primarily small trucks and passenger cars). This test procedure is concerned primarily with the maximum noise produced during acceleration and deceleration of a passing vehicle.

2.2 Procedure Reference. The following test procedure is based on Standards and Recommended Practice established by the Society of Automotive Engineers, Inc. These include: SAE Standard J331 *Sound Levels for Motorcycles and Motor-Driven Cycles*, SAE Recommended Practice J366 *Exterior Sound Level for Heavy Trucks and Buses*, and SAE Standard J986 *Sound Level for Passenger Cars and Trucks*.

2.3 Selection of Test Area and Conditions. The surface over which the test vehicle is to be operated shall be sufficiently smooth so that abnormal tire noise is not produced. Normal concrete or asphalt road surfaces are adequate.

The location shall be flat open area free of any large reflective surfaces, such as signboards, buildings, trees, shrubs, hillsides and parked vehicles, within a distance of 100 ft of the microphone and within 100 ft of the centerline of the path of the vehicle from the point where the throttle is open to the point where the throttle is closed. (Figure C-1)

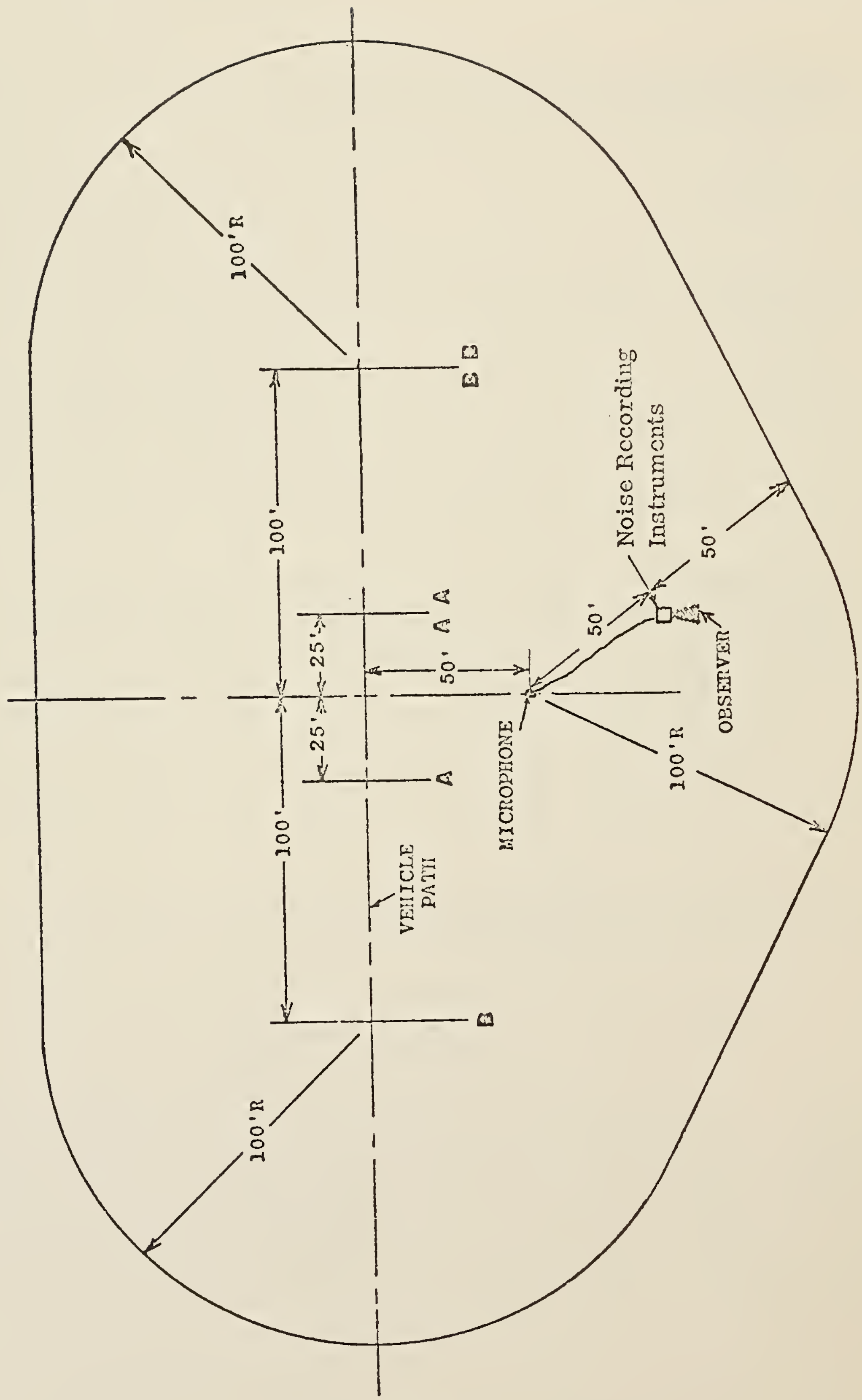

100'R
100'R
100'R
B B
B
A A
A
100'
100'
25'
25'
50'
50'
50'
VEHICLE PATH
MICROPHONE
Noise Recording Instruments
OBSERVER

Figure C-1

The surface within the measurement area shall be pavement and free of powdery snow, grass, loose soil or ashes.

Sound measurement shall not be conducted when wind velocity exceeds 12 mph.

2.4 Personnel Qualifications. Calibration and operation of the noise measuring instrumentation shall be performed by persons trained and qualified in the techniques of noise measurement and the operation of noise measuring instrumentation.

2.5 Instruments Required. Instrumentation used in making vehicle noise measurements shall be selected by technically trained personnel and shall meet SAE Recommended Practice J184 *Qualifying A Sound Data Acquisition System*.

2.6 Equipment Set-Up. Connect a 60 ft extension cable between the microphone and the sound level meter. Attach microphone to a tripod and turn the instrument on. Raise the tripod so that the microphone is 4 ft (± one-half foot) above the ground. Locate the tripod so that the microphone is 50 ft (± one foot) from the center of the lane over which the test vehicles are to be operated. The normal to the vehicle path from the microphone shall establish the microphone point on the vehicle path. (Figure C-1). The microphone shall be oriented relative to the source of the sound in accordance with the instrument manufacturer's instructions to provide a uniform frequency response.

Bystanders occupying positions in the vicinity of the test vehicle or the microphone will influence the test results. No bystander shall be closer than 50 ft from the microphone and the vehicle being tested.

Set up the sound level meter and recorder at least 50 ft from the noise measuring microphone. Connect the output of the sound level meter to the recorder. Set the sound level meter to A-Weighting and "Fast" meter.

External (end-to-end) calibration checks shall be made before and after each period of use and at intervals not exceeding one hour when the instrument is in use longer than this time.

2.7 Transmission Gear Selection. Passenger cars, light trucks, and buses that are equipped with automatic transmissions or three or four speed manual transmissions shall make test runs as outlined in low gear. Vehicles equipped with four speed manual transmissions shall make additional runs in second gear. Vehicles with five speed manual transmissions shall be operated in second gear. Vehicles equipped with an "overdrive" shall not make test runs with the overdrive engaged.

Vehicles which reach maximum rated engine speed at less than 30 mph or before reaching a point 25 ft beyond the microphone line shall be tested in the next higher gear.

Wheel slip that affects the maximum noise level shall be avoided.

2.8 Vehicle Test Procedure. Sufficient preliminary runs shall be made to familiarize the driver with the vehicle operation and to ensure that the engine has reached normal operating temperature.

Vehicles being tested shall make at least four runs in each direction with a one-minute wait between each run.

2.8.1 Large Vehicle Tests. Trucks, truck tractors and buses having a manufacturer's gross vehicle weight rating of 6000 lb or more shall be operated under the condition of load, acceleration, deceleration and gear selection that is found to produce the maximum noise emission at speeds up to 35 mph.

2.8.2 Small Vehicle Tests. Passenger cars, light trucks, truck tractors and buses having a manufacturer's gross vehicle weight of less than 6000 lb shall proceed down the test lane at a constant approach speed of 30 mph. When the front of the vehicle reaches line A or AA (Fig. C-1), a wide open throttle will be applied. A wide open throttle shall be maintained, provided maximum rated engine speed is not exceeded, until the rear of the vehicle has passed line B or BB (Fig. C-1). When engine overspeed occurs or when vehicle reaches line B or BB, release throttle.

2.8.3 Motorcycle Tests. Motorcycles shall follow the procedures outlined in the paragraph above except that they shall proceed down the test lane at a steady speed corresponding to either an engine speed of 60% of the speed at which the engine develops maximum horsepower, or at 30 mph, whichever is lower. In most cases operation in second gear will meet this requirement.

2.9 Deceleration Test. Deceleration tests need be conducted only when there is an indication that the deceleration noise might exceed the acceleration noise. When conducting a deceleration test, the vehicle shall proceed along the test path in the gear which was used for acceleration test and at a constant approach speed equal to the maximum rated engine speed. When the front of the vehicle reaches a point 25 ft beyond a line through the microphone, the throttle shall be closed as rapidly as possible.

2.10 Calculating Test Results. The sound level readings for determining compliance of new motor vehicles shall be obtained by making at least four measurements for each side of the vehicle. The reading recorded shall be the highest dB(A) sound level obtained as the vehicle passes by, disregarding unrelated peaks due to extraneous ambient noises. The A-Weighted sound level (with fast meter response) for each side shall be the average of the two highest readings on that side which are within 2 dB of each other. The noise level reported for the vehicle shall be the sound level of the loudest side of the vehicle. Obvious vehicle malfunction shall nullify the test. Measurements shall be made only when the A-Weighted ambient sound level, including wind effects, due to all sources other than the vehicle being measured is at least 10 dB(A) lower than the sound level of the vehicle.

3. MEASUREMENT OF NOISE FROM POWERED DEVICES

3.1 Purpose. The following test procedure is to be used to determine that the maximum noise emitted by engine- or motor-powered devices offered for sale shall meet the noise limits stated in the Noise Regulations. This procedure includes the noise testing of construction and industrial mobile equipment, agricultural equipment, engine and motor-powered equipment and pneumatic powered equipment.

3.2 Procedure Reference. The noise test procedure is based on the SAE Standard J952 entitled *Sound Levels for Engine Powered Equipment*.

3.3 Test Site. The test area shall consist of a flat open space, free of any large reflecting surfaces such as a signboard, building, parked vehicles or hillside located within 100 ft of either the microphone or the equipment being measured (see Fig. C-2).

The location or path of the equipment travel shall be over a surface which is typical of the particular machine application. The ground surface between the equipment and microphone shall be smooth, hard packed dirt, and shall be free of acoustically absorptive material such as snow or grass.

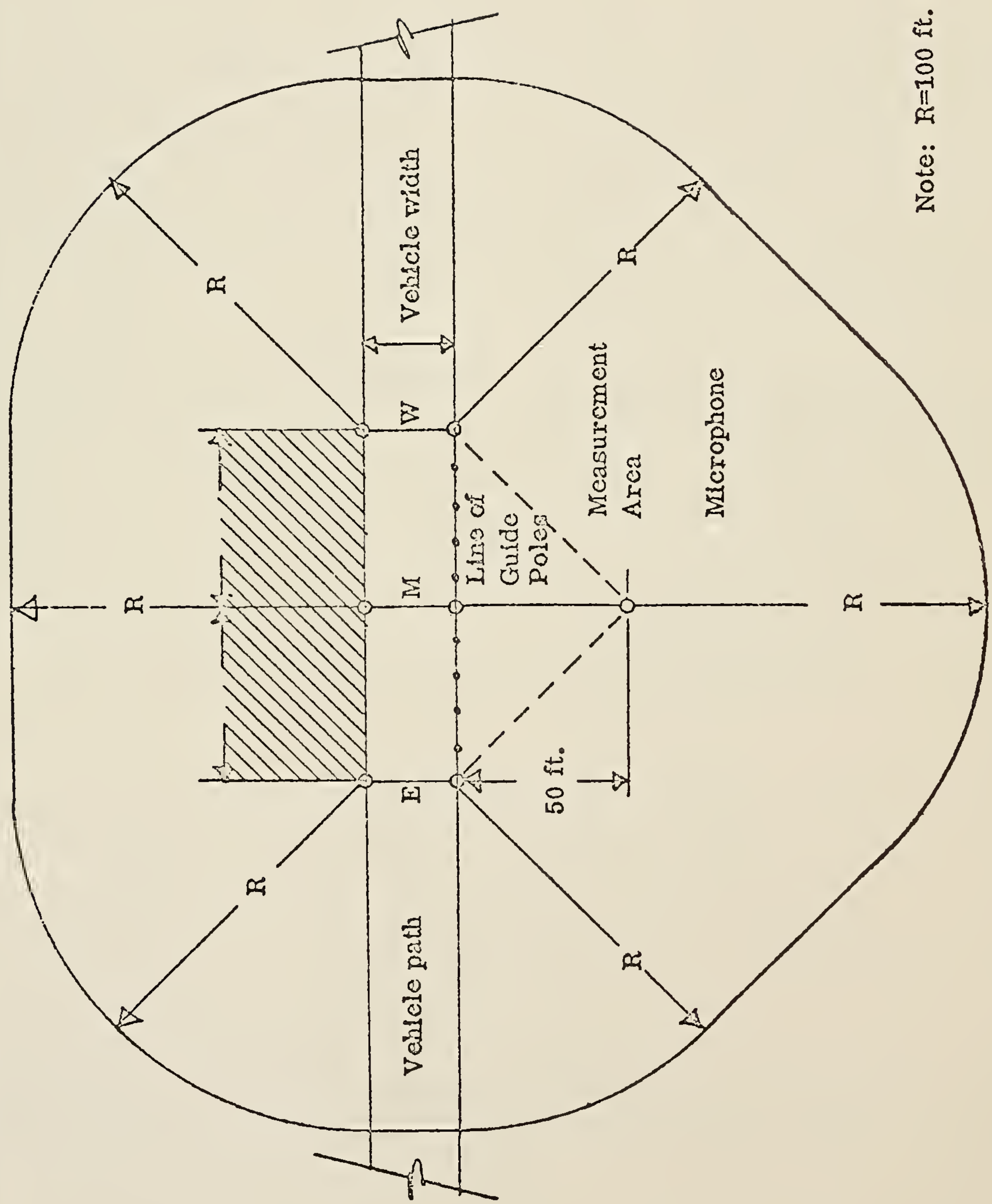
The location or path of equipment travel shall be concrete, asphalt, or similar hard material except for moving tests of steel wheel or track-type mobile equipment which shall be hard-packed dirt.

FOR ACCELERATION TESTS:

33 ft between E-M and W-M
Acceleration zone

FOR MOVING TESTS:

Min. of two vehicle lengths
Zone of steady state operating conditions



Note: R=100 ft. radius

FIGURE C-2 MINIMUM UNIDIRECTIONAL TEST SITE

3.4 Personnel Qualifications. Persons selected to conduct the noise measurement testing described below shall have been trained and qualified in the techniques of sound measurement and the operation of sound measuring instruments.

3.5 Instruments Required. Instrumentation used in making noise measurements shall be selected by technically trained personnel and shall meet SAE Recommended Practice J184 *Qualifying a Sound Data Acquisition System.*

3.6 Instrument Set-Up. Connect a 60 ft extension cable between the microphone and the sound level meter. Attach microphone to a tripod and turn the instrument on. Raise the tripod so that the microphone is 4 ft (± one-half foot) above the ground. For mobile equipment locate the tripod so that the microphone is 50 ft (± one foot) distance normal from a major side surface along a path of straight line travel.

For stationary tests locate the tripod so that the microphone is at a distance of 50 ft (± one foot) from the four major surfaces of the equipment. Generally four major surfaces refer to front, rear, and sides of an imaginary box that would just fit over the machine but does not include attachment items such as buckets and booms (see Fig. C-3).

The microphone shall be oriented relative to the source of the sound in accordance with the instrument manufacturer's instructions to provide a uniform frequency response.

When using a windscreen it should be calibrated for the type of noise source being measured and data corrected if necessary. It is recommended that measurements be made only when wind velocity is below 12 mph.

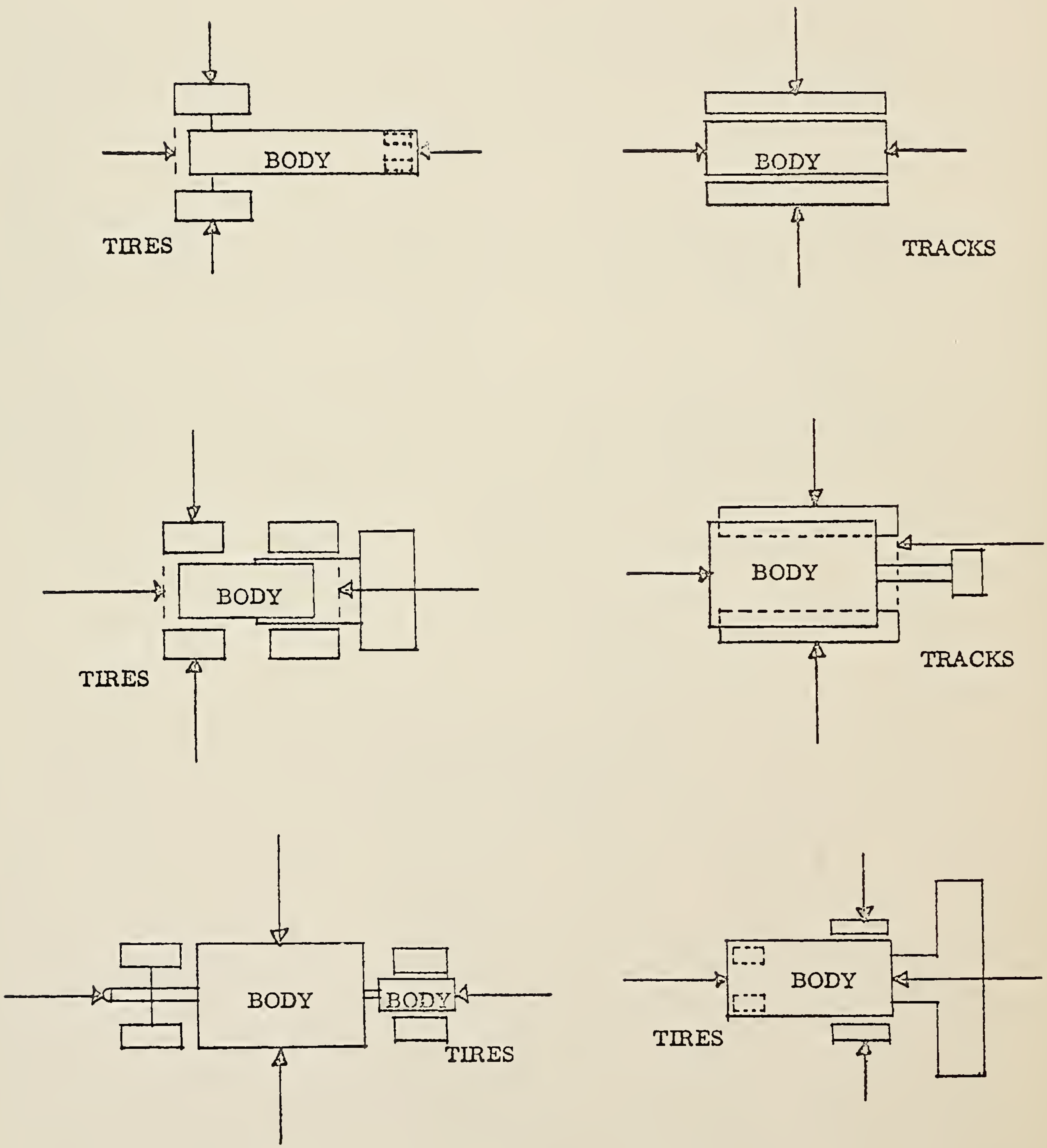


FIGURE C-3 MAJOR SURFACE OUTLINES

Bystanders occupying positions in the vicinity of the equipment under test or the microphone will influence the test results. No bystander shall be closer than 50 ft from the microphone and the equipment being tested, except during a test for discrete frequency components on equipment that is stationary.

Set up the sound level meter and recorder at least 50 ft from the noise measuring microphone. Connect the output of the sound level meter to the recorder. Set the sound level meter to A-Weighting and "Fast" meter.

Measurements shall be made only when the ambient noise level due to all sources other than the vehicle being measured, including wind effects, is at least 10 dB(A) lower than the level of noise being measured.

External (end-to-end) calibration checks shall be made before and after each period of use and at intervals not exceeding one hour when the instrument is in use longer than this time.

3.7 Stationary Test. Operate the stationary equipment at the combination of load and speed which are typical of its normal use and produce the maximum sound level without violating the manufacturer's operation specifications. For stationary test of mobile equipment the engine shall be operated at maximum normal attainable speed with no load. Pneumatic equipment shall be operated as specified in *CAGIPNEUROP Test Code for the Measurement of Sound From Pneumatic Equipment* prepared by the Compressed Air and Gas Institute.

3.8 Steady-State Moving Tests. Mobile equipment shall be operated in an intermediate forward gear over a path of travel typical for its operation with the engine at its rated speed and load. The load can be obtained with any combination of rolling resistance, blading, drag load, or vehicle brakes. Intermediate is intended to mean third gear for machines with five or six gears, etc. Hydrostatic or electric drive equipment will be operated at one-half their maximum ground speed and rated engine load. If the condition of rated engine speed at load cannot be obtained due to stall (for instance as on some loaders), wheel slip, or other reasons, the equipment shall be operated in the same intermediate gear at maximum attainable engine speed and no load.

3.9 Acceleration Tests. Only rubber-tired mobile equipment that is normally roaded between job sites and does not require special over-width or over-weight permits for road travel should be run through the acceleration test. The path of equipment travel for this test shall be concrete, asphalt, or similar hard material.

The mobile equipment should approach line E headed toward line M in Fig. C-2 at a steady speed of 30 mph or three-quarters of the maximum speed whichever is lower. Where alternate forward drive positions are available that position that results in the highest mean acceleration of the vehicle between line E and line W should be selected. When the front of the vehicle reaches line E the throttle is fully opened as rapidly as practicable and held there until the rear of the vehicle reaches line W and then the throttle is closed as rapidly as possible.

Equipment that has major noise generating machinery such as elevating scraper, combine or field cutter shall have this machinery in operation during the STATIONARY AND STEADY-STATE MOVING TESTS.

3.10 Noise Measuring Procedure. For stationary tests record the highest sound level obtained at a distance of 50 ft from the four major surfaces of the equipment.

Because of the interference between direct sound waves and those reflected from the ground, large errors may occur when strong discrete frequency components are present. Tests shall be made by moving the microphone vertically approximately ± 2 ft at each location where strong discrete frequency components are suspected. The maximum value of the sound level observed during this test will be the value reported. This discrete frequency component test is the only condition where a bystander is permitted near the noise measuring microphone. His position should be to the side of the microphone relative to a line between the microphone and the equipment under test.

For mobile equipment, take measurements at 50 ft distance normal from a major side surface along a path of straight line travel. Without changing microphone location, repeat the above procedure in opposite direction of travel. The applicable reading will be the highest sound level obtained from the equipment as it moves along the line of path travel (see Fig. C-2).

Observations for each test condition shall be repeated until the number of readings equals or exceeds the range in decibels of the A-Weighted sound levels obtained. At least four measurements shall be made. Readings more than 6 dB(A) below the maximum reading for each test condition shall not be considered valid. The averages of all valid readings shall be reported as the sound level of the particular equipment being tested for that particular test condition.

3.11 Impact, Impulsive or Percussive Noise Measurement. These results will be considered in compliance with noise limits provided the equipment or machinery does not produce predominantly impact or percussive-type noise. If the noise is predominantly impact, impulsive, or percussive the equipment or machinery is not considered in compliance unless the measured noise levels are at least 5 dB(A) below the noise level limits. NOTE: To be classified as impact, impulsive or percussive noise, an individual noise burst must have a duration of less than 0.25 sec measured between the instants at which the instantaneous sound pressures have a value equal to one-half the peak value. If the noise is repetitive, the repetition rate of the burst must be less than 5/sec and the arithmetic average of the peak pressure levels of ten consecutive bursts in the train must be more than 15 dB above the unweighted (rms) sound pressure level in the presence of the impulses.

4. ZONING DISTRICT BOUNDARY AND PROPERTY LINE NOISE MEASUREMENTS

4.1 Purpose. The following test procedure is to be used to determine the noise levels along zoning district boundaries and along property lines. The procedure permits the use of a hand-held sound level meter to perform noise surveys with limited accuracy and describes more detailed measurement techniques for determining noise levels in octave or narrower frequency bands with high accuracy.

4.2 Personnel Qualifications. Persons selected to conduct the noise measurements described below shall have been trained and qualified in the techniques of sound measurement and the operation of sound measuring instruments.

4.3 Selecting Measuring Instrumentation.

4.3.1 Survey Method. The instrumentation for conducting a noise survey shall conform with ANSI Standard SL.4-1961 *Specification for General Purpose Sound Level Meters* or IEC Standard 123-1961 *Recommendations for Sound Level Meters*. The meter shall be set for "Fast" response and the A-Weighted network.

4.3.2 Precision Method. Instrumentation for making accurate noise level measurements requires laboratory quality instrumentation meeting the following standards:

ANSI Standard SL.4-1961 *Specification for General Purpose Sound Level Meters*

ANSI Standard S1.12-1967 *Specifications for Laboratory Standard Microphone*

ANSI Standard S1.11-1966 *Specifications for Octave, One-Half Octave and One-Third Octave Band Filter Sets*

IEC Standard 179-1965 *Precision Sound Level Meters*

IEC Standard 225-1966 *Octave, One-Half Octave and One-Third Octave Band Filters Intended for the Analysis of Sounds and Vibrations*

SAE Recommended Practice J184 *Qualifying a Sound Data Acquisition System*

The precision method may be used to measure A-Weighted noise level, octave, one-third octave band frequency analysis, or narrower frequency band analysis when deemed necessary. The "Fast" meter response or equivalent shall be used on the sound level meter or other read-out device.

4.4 Instrumentation Set-Up. Noise measurements shall normally be made with microphone positioned 4 feet(± one-half foot)above the ground. Other microphone heights may be used if they prove to be more practicable as, for example, in making measurements near an open window; the microphone shall be centered on the open window and outside at a horizontal distance of one to two feet from the plane of the window. All microphone positions shall be described in the recording of the data. The microphone shall be oriented relative to the source of noise (if any) in accordance with the instrument manufacturer's instructions to provide a uniform frequency response.

4.5 Measurement Conditions. Measurements shall be made only when wind velocity is below 12 mph. If a wind screen is used it should be calibrated for the type of noise being measured and the

data corrected, if necessary. Because bystanders may have an appreciable influence on the microphone response, the instrument manufacturer's specifications for location of the observer relative to the microphone (meter) shall be followed.

4.6 Calibration. Instrument manufacturer's recommended calibration practice of the instruments shall be made at the appropriate times. Field calibration should be made immediately before and after each complete test.

4.7 Operation Procedures. Currently under development within working committees of ANSI is a set of procedures applicable to the type of measurements needed here. The techniques represent best practices using up-to-data equipment. Specific procedures are available in draft form, and are slated for eventual publication when released by ANSI.

4.8 Impact, Impulsive or Percussive Noise Measurement. Noise that is predominantly impact, impulsive or percussive is not considered in compliance unless the measured levels are at least 5 dB(A) below the statutory limit. NOTE: To be classified as impact, impulsive or percussive noise, an individual burst must have a duration of less than 0.25 sec measured between the instants at which the instantaneous sound pressures have a value equal to one-half the peak value. If the noise is repetitive, the repetition rate of the bursts must be less than 5/sec and the arithmetic average of the peak pressure levels at ten consecutive bursts in the train must be more than 15 dB above the unweighted (rms) sound pressure level in the presence of the impulses.

APPENDIX D

Published Sources of Noise Control Information

This report contains brief descriptions of specific quieted devices and has suggested how noise control technology might be applied to specific situations in the City of Boston. The techniques of noise control are applicable to almost every situation where there is objectionable noise. In the majority of cases where annoyance is still present, it is due to a lack of action rather than the lack of available knowledge. The following listing presents a good sample of available material on the technology of ncise control. An office or person dealing with matters in this field would be well-advised to have this material, if not at hand, readily accessible.

I. TEXTS AND HANDBOOKS

Noise Reduction, Leo L. Beranek. New York, McGraw-Hill Book Co., Inc., 1960.

Handbook of Noise Control, Cyril M. Harris. New York, McGraw-Hill Book Co., Inc., 1957.

Acoustics, Leo L. Beranek. New York, McGraw-Hill Book Co., Inc., 1954.

Shock and Vibration Handbook, Cyril M. Harris and Charles E. Crede. New York, McGraw-Hill Book Co., Inc., 1961. 3 Vols.

Fundamentals of Acoustics, 2nd Ed., Lawrence E. Kinsler and Austin R. Frey. New York, John Wiley and Sons, 1962.

Sound, Noise, and Vibration Control, Lyle F. Yerges. New York, Van Nostrand Reinhold, 1969.

Noise as a Public Health Hazard: Proceedings of the Conference, ASHA Reports 4, W. Dixon Ward and James E. Fricke (eds.), Washington, D.C., American Speech and Hearing Association, 1969.

Transportation Noises: A Symposium on Acceptability Criteria, James D. Chalupnik (ed.), Seattle, University of Washington Press, 1970.

Acoustics Handbook: Application Note 100. Palo Alto, California, Hewlett-Packard Company, 1968.

Handbook of Noise Measurement. West Concord, Massachusetts, General Radio Company, 1967.

The Application of the Bruel & Kjaer Measuring Systems to *Acoustic Noise Measurements*. Jens T. Broch. Bruel & Kjaer, 5111 West 164 Street, Cleveland, Ohio 44142.

The Application of the Bruel & Kjaer Equipment to *Mechanical Vibration and Shock Measurements*. Bruel & Kjaer, 5111 West 164 Street, Cleveland, Ohio 44142.

II. PERIODICALS

Journal of the Acoustical Society of America, Vol. I - 1929+
American Institute of Physics
335 East 45 Street
New York, New York 10017

Applied Acoustics, Vol. I - 1968+
Elsevier Publishing Co., Ltd.
Ripple Road
Barking, Essex
England

Sound and Vibration, Vol. I - 1967+
Acoustical Publications, Inc.
27101 East Oviatt Road
Bay Village, Ohio 44140

Noise Control, Vol. I - 1955, Vol. VII - 1961 (no longer published)

Sound, Vol. I - 1962, Vol. II - 1963 (no longer published)

III. MISCELLANEOUS

Performance Data: *Architectural Acoustical Materials*. Published annually by Acoustical and Insulating Materials Association, 205 West Touhy Avenue, Park Ridge, Illinois 60068.

Acoustics, Vibration, Mechanical Shock, and Sound Recording. Complete packet of standards. Available from American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018.

Guide for Conservation of Hearing in Noise. Revised 1957. American Academy of Ophthalmology and Otolaryngology, 15 Second Street, S.W., Rochester, Minnesota 55901.

REFERENCES

1. NASA Langley Research Center and Old Dominion University, "Transportation Noise Pollution: Control and Abatement," (1970).

2. Bolt Beranek and Newman Inc. Report 2005, "Technical Background for Noise Abatement in HUD's Operating Programs," September 1970.

3. Bolt Beranek and Newman Inc. Report No. 1861, "Evaluation of Highway Noise," January 1970.

4. Bolt Beranek and Newman Inc. Report No. 1452, "Noise and Vibration Effects Study: New Orleans Riverfront Expressway," October 1966.

5. Bolt Beranek and Newman Inc. Report No. 1709, "A Comprehensive Survey of the Noise in Communities Around Boeing Field, Seattle," January 1969.

6. Federal Commission for Noise Abatement (1963) as quoted in Organisation for Economic Co-Operation and Development "Report on Urban Traffic Noise," August 1970.

7. Nordic Committee for Building Regulations, "Noise from Highways," December 1966.

8. *Noise*, A. Wilson (ed.), London, Her Majesty's Stationery Office, 1963.

9. Federal Housing Administration Technical Study FT/TS-26, "Noise in Urban and Suburban Areas, Results of Field Studies," March 1968.

10. Boston Redevelopment Authority, *Transportation Facts for the Boston Region,* 1968-69 Edition.

11. Wilbur Smith Associates, *Comprehensive Traffic and Transportation Inventory,* prepared for Boston Regional Planning Project, September 1965.

12. Boston Traffic and Parking Commission, *Cordon Count-Downtown Boston,* 1964.

13. Boston Traffic and Parking Commission, *Intersection Turning Movement Count Sheets,* 1966-1969.

14. "The First Quiet Portable Compressor," *Sound and Vibration* 3(6), May 1969.

15. Bolt Beranek and Newman Inc. Report No. 2052, "The Acoustical Treatment of Stations to Alleviate Wheel-Squeal Noise," October 1970.

16. Kirschner, Francis, "Control of Railroad Wheel Screech Noise," Report of the Sixth International Congress on Acoustics, August 21-28, 1968, IV-F-2-8, International Council of Scientific Unions, UNESCO Subvention – 1968 – DC/2.1/414/26.

17. Parsons-Brinckeroff-Tudor-Bechtel Report No. 8 to the Bay Area Rapid Transit District, "Acoustic Studies," June 1968.

18. U.S. Department of Transportation Report No. OST-ONA-70-1, "Noise Generated by Subways Aboveground and in Stations," January 1970.

19. R.W. Young, "Scales for Expressing Noise Levels," contained in Reference 20.

20. *Transportation Noises: A Symposium on Acceptability Criteria,* James D. Chalupnik (ed.), University of Washington Press, 1970.

21. Melville C. Branch and R. Dale Beland, "Outdoor Noise and the Metropolitan Environment – Case Study of Los Angeles with Special Reference to Aircraft," Department of City Planning, Los Angeles, California, 90012, July 1970.

22. Webster, J.C. and R.S. Gales, "Noise Rating Methods for Predicting Speech Communication Effectiveness," contained in Reference 20.

23. Bolt Beranek and Newman Inc. Report No. 1922, "Ratings for the Assessment of Community Noise Problems," December 1969.

24. Beranek, L.L., *Acoustics,* McGraw-Hill Book Co., New York (1954).

25. Thiessen, G.J., and N. Olson, "Community Noise-Surface Transportation," *Sound and Vibration* 2(4); 10-16 (1968).

26. National Research Council of Canada, "A Brief Study of Rational Approach to Legislative Control of Noise," Report #APS-467, N.R.C. 10577, Ottawa, 1968 (includes appendix on "Noise Studies and By-Laws in Various Places").

27. Lang, Judith and Gerd Jansen, "Report on the Environmental Health Aspects of Noise Research and Noise Control," United Nations, World Health Organization, May 1967.

28. Schieber, J.P., "Contributions of Physiological Studies to the Problem of Determining Areas of Acoustic Comfort during Sleep," *Revue d'Acoustique* 3(10): 104-112 (1970).

29. U.S. Department of Labor, "Walsh Healey Public Contracts Act," Safety and Health Standards, Federal Register 35, 7946-7954, May 20, 1969) (revised July 15, 1969).

30. Occupational Safety and Health Act of 1970 (Public Law 91-596) December 29, 1970.

31. Cohen, Alexander, Joseph Anticaglia, and Herbert H. Jones, "'Sociocusis' – Hearing Loss from Non-Occupational Noise Exposure," *Sound and Vibration* 4(11):12-20 (1970).

32. Berland, Theodore, "Noise – The Third Pollution," Public Affairs Pamphlet No. 449, June 1970, The Public Affairs Committee, 381 Park Avenue South, New York, New York 10016.

33. Jansen, Gerd, "Effects of Noise on Physiological State," published in *Noise as a Public Health Hazard: Proceedings of the Conference, ASHA Reports 4*, The American Speech and Hearing Association, Washington, D.C., 1969.

34. *Noise as a Public Health Hazard: Proceedings of the Conference, ASHA Reports 4*, The American Speech and Hearing Association, Washington, D.C., 1969.

35. Mery, J., "Studies of Physiology," *Revue d'Acoustique* 3 (10): 113-122 (1970).

36. Department of Housing and Urban Development, Proposed Circular: "Noise Abatement and Control, Department Policy, Implementation Responsibilities and Standards" (1970).

37. *Physiological Effects of Noise*, Welch, Bruce L. and Anne Marie S. Welch (eds.), New York, Plenum Publishing Corp. (1970).